E&A

TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

COMMONWEALTH INST.
ENTOMOLOGY LIBRARY
15 JAN 1962
SERIAL Ab. 3
SEPARATE

VOLUME CXVI NUMBER 4
OCTOBER-DECEMBER, 1960

[1961]

ROGOR 40

The new safe insecticide for use on

Stemborer on Paddy
Agromyza fly on Beans
Cucurbit fly on Cucurbits
Aphids on Cowpea

Enquiries to :

FISONS (Ceylon) LTD.

P. O. Box 69,
COLOMBO

FISONS PEST CONTROL

FERTILISERS

For all Crops

The Ceylon MANURE WORKS

Works : Kelaniya—*Offices :* Colombo

2——J. N. R 18288—1,510 (7/61).

PHYTOMORPHOLOGY

Official organ of the

INTERNATIONAL SOCIETY OF PLANT MORPHOLOGISTS

PHYTOMORPHOLOGY is devoted to all branches of plant morphology including original articles and critical reviews, and is edited by Professor P. Maheshwari in co-operation with a number of advisory editors. Articles accepted in English, German and French. The membership fee of the Society is as follows :—

Life Membership—

Rs. 200 (India), £ 20 or $ 56.20 (Foreign)

Annual Membership—

Rs. 20 (India), £ 2 or $ 5.62 (Foreign)

PHYTOMORPHOLOGY is supplied to members without additional charge. Institutions can subscribe at Rs. 30 (India), £ 2.10 or $ 7.04 (Foreign). A few sets of back volumes still available at the following rates :

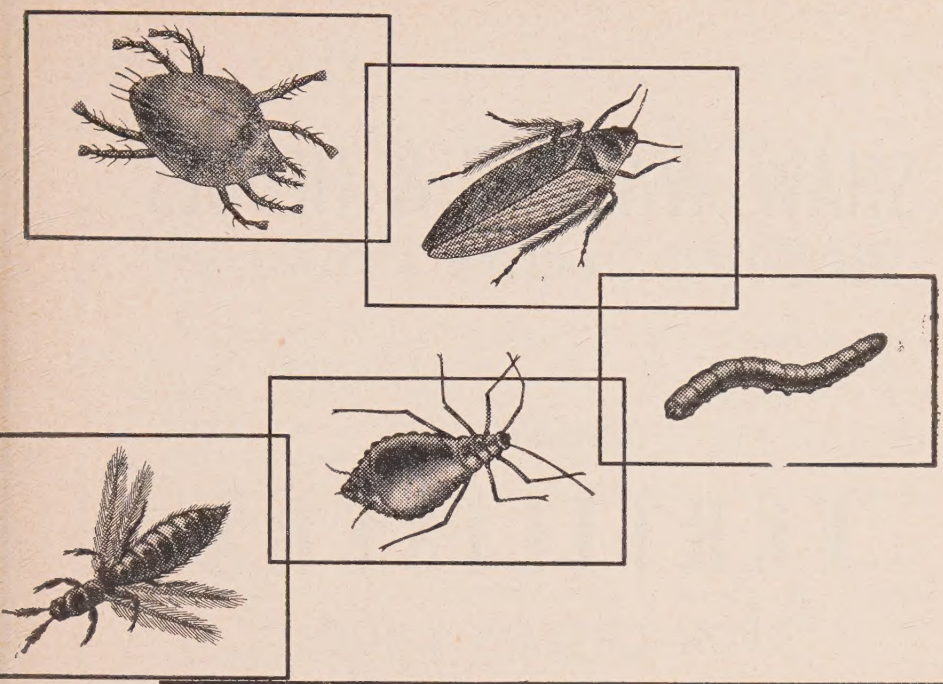
Volume 1 (1951) .. Rs. 45 ; £ 3.10 or $ 9.85

Volumes 2-9 (1952-1959) .. Rs. 40 ; £ 3 or $ 8.45 per volume.

Payable to

INTERNATIONAL SOCIETY OF PLANT MORPHOLOGISTS by cheque (please add bank commission), bank draft, or UNESCO coupons.

Address editorial matters to the Editor, PHYTOMORPHOLOGY and other correspondence to the Secretary-Treasurer, INTERNATIONAL SOCIETY OF PLANT MORPHOLOGISTS, Department of Botany, University of Delhi, DELHI 8, India.



MALATHION

For wider-range insect control with greater safety

Growers of every kind can benefit from the many outstanding advantages that MALATHION offers in controlling insect pests. No other insecticide gives a better measure of control over such a wide range of pests. MALATHION ensures multiple control where many insects have to be dealt with. Yet because of its greater margin of safety in handling, it affords additional protection to those who handle it. MALATHION is compatible with most other spray materials. Its residues disappear quickly. It has a deadly action against numerous pests that infest fruit and vegetables, flowers and ornamentals. In this it safeguards the grower's profits as well as his crops.

MALATHION *is available in formulated insecticides through local dealers.*

CYANAMID

CYANAMID OF GREAT BRITAIN LTD
FARM AND HOME DIVISION
BUSH HOUSE, LONDON, W.C.2

SHAW WALLACE & HEDGES
LIMITED

Specialists in

FERTILISERS
FOR CEYLON CROPS

Sole Suppliers of

STERAMEAL
(Sterilised Animal Meal Black Label)

THE IDEAL DRESSING
for
NURSERIES and YOUNG PLANTS

No. 363, Kollupitiya Road, Colombo 3

Telephone : 78271

NEW PUBLICATIONS OF THE INDIAN CENTRAL COCONUT COMMITTEE

THE COCONUT PALM—A MONOGRAPH

Compiled by Dr. K. P. V. Menon, Director, Central Coconut Research Station, Kayangulam, and Dr. K. M. Pandalai, Joint Director, Central Coconut Research Station, Kasaragod, "The Coconut Palm—A Monograph" is a comprehensive treatise on all problems connected with the coconut industry and fills a long gap of scientific information that has accumulated in coconut research during the last two decades.

The book contains 384 pages of size $8\frac{3}{4}'' \times 11\frac{1}{2}''$ 150 illustrations and 19 colour plates. It has been priced at Rs. 43/- (for buyers within India, Pakistan and Ceylon) and at £ 4-10-0 and $ 13.00 (for foreign buyers) inclusive of postage, etc.

"THE COCONUT ATLAS OF INDIA"

is a beautifully illustrated publication that tells in maps, charts and graphs and tells in a simple and effective manner acreage and production of coconuts in India and the world, trends in import and export and trends in prices of coconut, copra and coconut oil in India and some of the important coconut growing countries of the world.

Beautifully printed on offset paper with rexine cover the book contains 98 pages of size $11\frac{1}{2}'' \times 9''$ and is priced at Rs. 18/- (for buyers within India, Pakistan and Ceylon) and at £ 2. 0. 0. and $ 6.00 (for foreign buyers) inclusive of postage, etc.

For copies apply to :

The Secretary,
Indian Central Coconut Committee,
Ernakulam-1, (Kerala)

or

The Business Manager,
Indian Council of Agricultural Research,
Krishi Bhavan, Dr. Rajendra Prasad Road, New Delhi-2

ANNOUNCING

THE CEYLON COCONUT JOURNAL

A Quarterly Magazine dealing with the Coconut Industry in Ceylon and its Overseas Trade

JANUARY APRIL JULY OCTOBER

First Issue—October, 1956

Special Features

- Factual and Statistical Reviews of Ceylon's Trade in Coconut Products.
- Coconut Gazetteer containing names and addresses of Coconut Merchants, Millers, Shippers, Auctioneers & Brokers, Dealers.
- Planting Notes.
- Trade Offers and Enquiries, Local and Foreign : Excellent media for advertisement.

ADVERTISEMENT RATES ON APPLICATION

PRICE PER COPY Rs. 2·50

Annual Subscription : Local Rs. 10/– (including postage)
Foreign £ 1 (Including postage)

Write for particulars to : **PRINTING HOUSE**
256, Bank of Ceylon Building, York Street, COLOMBO 1

GOVIKAM SANGARAWA

(QUARTERLY)

The only Farm Magazine in Sinhala

Annual Subscription .. .. Re. 1'00
Price per Copy .. .. -'25 cts.

Apply :

THE AGRICULTURAL OFFICER
(Publicity)
No. 19, SAUNDERS PLACE
COLOMBO 12
(P. O. Box 636)

COMMONWEALTH ECONOMIC COMMITTEE

Recent Publications of the Committee include

Commonwealth Trade, 1954–55	1s. 7½d
Commonwealth Agriculture (1955)	2s. 7½d
Annual Report, 1954–55	10½d

Prices include Postage

Commodity Series

This series reviews the significant trends in world production, consumption, trade and prices for the commodities concerned. Volumes of special interest to Ceylon in the Series, which are revised annually, are the following :—

Plantation Crops (with sections on tea, rubber, cocoa and spices)	5s. 6½d
Grain Crops (with sections on rice and wheat flour) ..	5s. 6½d
Vegetable Oils and Oilseeds (with section on coconut palm products)	5s. 7½d
Industrial Fibres (with section on coir)	5s. 7½d

Prices include Postage

Periodical Intelligence Services issued by the Committee include :

Grain Bulletin (monthly with Rice Supplement) for which the subscription rates including postage are, £2 per annum for the Grain Bulletin including the Rice Supplement and £1 per annum for the Rice Supplement only.

Orders for these publications should be sent direct to—

The Secretary,
Commonwealth Economic Committee,
2, Queen Anne's Gate Building,
Dartmouth Street,
LONDON, S. W. 1.

PRESENTING

INSECTICIDES

The Hallmark of Reliability

Known the world over for their wide range of Insect control with efficacy

- FOLIDOL E. 605 47·6% EMULSION
  (With incorporated Skin Protectant)
- FOLIDOL 2% METHYL DUST

Controls all Pests of Paddy, Tobacco, Onions & Chillies

- DIPTEREX 80% SOLUBLE POWDER
- DIPTEREX 5% DUST

Controls all Pests of Vegetables, Paddy and Cotton, including Pod-Borers, Stem-Borers, Boll-worms, and Cutworms.

Also specific in Fly Maggot control in garbage and manure heaps.

For further details and technical advice, write to

Sole Agents :—

CHATHAM HOUSE LIMITED

P. O. Box 743

150 WARD PLACE BORELLA

COLOMBO 8

Telephone : **94191, 94801, 94802**

TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

VOLUME CXVI, NUMBER 4, 1960

Edited by

A. V. RICHARDS ESQ.

Director of Agriculture

CEYLON DEPARTMENT OF AGRICULTURE

SUBSCRIPTION RATES

(*Inclusive of Postage*)

	Annual	*Single Copy*
Local ..	.. Rs. 5·00 ..	.. Re. 1·50
India, Burma and Pakistan ..	.. Rs. 6·50 ..	.. Rs. 2·00
Other countries ..	.. Rs. 8·00 ..	.. Rs. 2·50

All subscriptions should be sent to the Publicity Officer, (Publicity) P. O. Box 636, Colombo, Ceylon

Exchanges should be addressed to the Librarian, Department of Agriculture, Peradeniya, Ceylon

ADVERTISEMENT RATES

(*Per Insertion*)

	Contract	*Casual*
Full Page	.. Rs. 30 0 ..	Rs. 35 0
Half Page	.. Rs. 17 0 ..	Rs. 19 0
Quarter Page	.. Rs. 8 50 ..	Rs. 10 0
Back Cover	.. Rs. 40 0 ..	Rs. 50 0
Inside Back	.. Rs. 35 0 ..	Rs. 40 0
Inside Front	.. Rs. 35 0 ..	Rs. 40 0

All correspondence and payments regarding advertisements should be addressed to the Agricultural Officer (Publicity), P. O. Box 636, Colombo, Ceylon

THE "TROPICAL AGRICULTURIST" IS REGISTERED AS A NEWSPAPER IN CEYLON

Vol. CXVI, No. 4 DECEMBER, 1960

CONTENTS

Page

EDITORIAL

Pest Control 241

LIME AS AN AMENDMENT FOR THE ACID LATERITIC RICE SOILS OF CEYLON

by F. N. Ponnamperuma, Chemist, Department of Agriculture, Ceylon 243

FERTILIZER EXPERIMENTS IN CULTIVATORS' FIELDS IN CEYLON

by F. N. Ponnamperuma, Chemist, Department of Agriculture, Ceylon 253

CHARACTERISTICS OF AN ILL-DRAINED RICE SOIL PROFILE IN BOMBUWELA

by Mervyn W. Thenabadu, Division of Botany, Department of Agriculture, Ceylon 267

MICROBIAL CONTROL : 1 : LABORATORY TESTS ON THE SUSCEPTIBILITY OF LEPIDOPTEROUS PESTS OF CABBAGE IN CEYLON TO COMMERCIALLY PREPARED *Bacillus Thuringiensis* BERLINER

by Mervyn D. de Silva, Research Officer in Entomology, Department of Agriculture, Ceylon 273

SOME OBSERVATIONS ON THE INSECT PESTS OF DHAL (CAJANUS CAJAN) AND THEIR CONTROL

by E. S. Thevasagayam and L. S. C. Canagasingham, Dry Zone Research Institute, Maha Illupallama, Ceylon 287

PRELIMINARY STUDIES ON THE CONTROL OF INSECT PESTS OF COTTON

by E. S. Thevasagayam and S. S. Mohinudeen, Dry Zone Research Institute, Maha Illupallama, Ceylon 299

METEOROLOGICAL REPORT

Summary for October to December, 1960 307

EDITORIAL

Pest Control

PRACTICALLY all cultivated crops are susceptible to attack by destructive pests that take heavy toll under conditions favourable to their spread. However, exact extents and nature of crop losses due to pests are hard to assess as many variables and complicating factors are involved. Pest infestations not only depress yields, but also lower the quality of produce and increase their costs of production, by involving the farmer in additional expenditure for the purchase of plant protection materials and equipment.

Development of pest control measures perhaps began with the earliest attempts of man to raise food crops. The practice of making sacrificial offerings to appease deities whose benevolence was considered vital for successful crop production must have been one of the widely adopted forms of crop protection for thousands of years. It is likely that cumbersome mechanical measures were also developed to supplement this practice.

Beginning with the accidental discovery of bordeaux mixture in 1882, an increasing number of chemicals have been employed for effective pest control. However, until the manufacture of calcium arsenate most of the chemicals such as Paris green and London purple, used for pest control, were originally intended for other industrial use. Discovery of their insecticidal properties was more by accident than by design. Early in the present century, however, the development and production of chemicals for the specific purpose of pest control became an established industry and several effective products became available for use in agriculture.

Development of DDT during World War II marked the beginning of a new era in the insecticide industry. Several organic insecticides adaptable to a wide range of crops and insects were soon on the market. These new insecticides have made possible the control of not only several persistant pests insensitive to the older insecticidal materials, but also some pests that appeared to develop resistance to repeatedly used insecticides.

Although the newer insecticides are very effective for pest control their improper and excessive use, and careless handling can make them extremely hazardous, as many of them are highly toxic to man and animals. There is also a school of thought that the cumulative effects of even the apparently harmless insecticides can induce disease conditions in man and animals. Whether or not there is sufficient

justification for entertaining such fears, the development of pest control measures that do not involve the use of materials toxic to man and animals is a laudable achievement.

Today, there is considerable interest in the development of effective pest control measures based on natural controls, so as to use insecticides only in a supplementary role. In the past there have been several notable achievements in regard to the employment of predators and parasites to combat tromblesome pests. The use of the pupal parasite, *Trichospilus pupivora*, to control the coconut caterpillar is one such example.

This number of the Tropical Agriculturist carries an article regarding the preliminary attempts made in this country to take advantage of a more recent development in the field of biological control, viz. Microbial Control. As reported in the article, the results are encouraging. However, any definite pronouncements as regards the practicability of microbial control in Ceylon must necessarily await the results of further investigations and trials.

LIME AS AN AMENDMENT FOR THE ACID LATERITIC RICE SOILS OF CEYLON

F. N. Ponnamperuma

(Chemist, Department of Agriculture, Ceylon)

THE mineral rice soils of the low country wet zone of Ceylon are strongly acid in reaction and deficient in bases. The adjoining highland is invariably ferruginous laterite. The productivity of these soils is low. Also the physiological disease of rice known as "bronzing" occurs frequently on these soils.

The results of an investigation reported elsewhere (1), showed that: (i) symptoms very similar to those of bronzing were associated with a high concentration of ferrous iron in the soil solution; and (ii) lime prevented the appearance of these symptoms. Lime as an amendment for acid lateritic rice soils was therefore tested on an imperfectly drained, strongly acid, clay loam at the Rice Research Station, Panagoda.

The soil had the horizon sequence,

$A_1pg/A_{12}g/Bg/BG/G$, after Kanno's notation (2) and the following chemical analysis:

pH	4·4
Organic matter	4·35 per cent.
Nitrogen	0·17 per cent.
Total exchangeable bases	0·72 m. e./100 gm.
Cation Exchange Capacity	7·10 m. e./100 gm.
Available P_2O_5 (Olsen)	12·5 ppm.
Available SiO_2	32 ppm.
Free Fe_2O_3	1250 ppm.

The levels of lime were 0, 3, and 6 tons slaked lime per acre. The plots were pegged out but not separated by ridges. Lime was applied in April 1956, only. The following fertilizer mixture was applied every season:

ammonium sulphate	100	lb./acre
concentrated superphosphate	50	
muriate of potsh	50	

Rice was grown on these plots for six seasons in succession with the results shown in Table I.

TABLE I

Mean Yields of Paddy lb./acre

Slaked lime (tons/acre) / *Season*	*0*	*3*	*6*	*S. E.*	*Mean response to 6 tons*
April, 1956–September, 1956	—	—	—	—	—
October, 1956–March, 1957	2,093	2,332	2,829	46	736
April, 1957–September, 1957	1,789	2,259	2,594	83	805
October, 1957–March, 1958	1,297	1,624	2,019	101	722
April, 1958–September, 1958	2,415	2,498	2,755	133	340
October, 1958–March, 1959	1,638	1,849	2,056	179	419

The responses to lime were very highly significant and linear in the range 0-6 tons per acre during the first three seasons for which the yields are available. A yield increase of over 700 lb. paddy per acre was obtained for three seasons in succession for one application of lime at 6 tons per acre.

The changes in pH value of the soil are shown in Table II.

TABLE II

pH value of the Dry Soil at the beginning of each Season

Season	*Slaked lime in tons/acre*		
	0	*3*	*6*
April, 1956*	4·4	6·5	7·6
October, 1956	4·9	5·9	6·6
April, 1957	4·9	5·2	5·9
October, 1957	4·8	5·1	5·4
October, 1958	4·9	5·0	5·3

* Two weeks after liming.

The decline in pH of the lime plots is due partly to loss of calcium by leaching and partly to diffusion and mass movement of calcium from the limed to the adjoining unlimited plots which were not separated by ridges.

In view of the linear response to lime in the range 0-6 tons per acre a fresh experiment was laid down with an additional level of lime, viz, 9 tons per acre. The results are summarized in Table III.

TABLE III

Mean Yields of Paddy in lb./acre in four-level Liming Trial

Slaked lime (tons/acre) / *Season*	*0*	*3*	*6*	*9*	*S. E.*	*Mean response to 6 tons*
April, 1957	1,458	1,693	2,111	1,385	69	653
October, 1957	1,017	2,029	1,978	1,874	202	1,007
April, 1958	2,171	1,969	1,978	2,056	129	— 175
October, 1958	2,153	2,797	2,949	2,783	115	796

Slaked lime at 9 tons per acre was injurious in the first two seasons. The responses to 6 tons per acre slaked were 653, 10,007, and 796 lb. per acre paddy during the first, second and fourth seasons respectively. In the third season there was no response to lime, probably because of unfavourable weather.

On the very poorly drained humic soils of Labuduwa, Karapincha, and Bombuwela, there was no significant response to lime.

In view of the marked and sustained benefits of lime on the acid lateritic soils at Panagoda, liming trials were set down on the moderately well drained to imperfectly drained acid lateritic soils of the low country wet zone of Ceylon.

LIME AND NITROGEN EXPERIMENTS

Object : To study the response of rice to slaked coral lime with and without nitrogen over a basal dressing of 40 lb. P_2O_5 per acre as conc. superphosphate and 50 lb. K_2O per acre as muriate.

Design : Randomized blocks of 4 plots replicated at several locations.

Plot size : $33' \times 16\frac{1}{2}'$.

Treatments : L_0N_0—No lime, no nitrogen.

L_0N_1—No lime, 40 lb. N. per acre as ammonium sulphate.

L_1N_0—6 tons lime per acre, no nitrogen.

L_1N_1—6 tons lime, 40 lb. N per acre as ammonium sulphate.

Soils : Strongly acid, moderately well drained to imperfectly drained brown clay loams.

Results : The limed treatments were characterized by their deep green colour, profuse tillering, and vigorous growth. The lime-plus-nitrogen treatment lodged badly. The individual plots yields in lb. per acre are presented in Table IV.

TABLE IV

Yields of Paddy (lb./acre), Mirigama Range

Location	L_0N_0	L_1N_0	L_0N_1	L_1N_1	*S. E.*
1	1,713	3,084	2,090	3,038	
2	526	2,764	1,041	1,840	
3	1,381	1,556	757	1,462	
4	1,150	1,913	1,209	1,698	
5	2,326	2,768	2,627	2,703	
6	2,517	3,665	2,339	2,377	
7	1,651	1,958	1,254	1,934	
8	2,842	2,962	2,593	2,891	
9	1,329	2,475	1,715	2,410	
10	2,157	2,990	2,814	2,590	
11	2,035	3,313	2,272	3,088	
12	1,806	2,855	2,014	2,227	
13	2,854	3,931	3,410	3,588	
Mean	1,868	2,788	2,010	2,452	83

The figures show that lime in the absence of fertilizer nitrogen unerringly produced an increase in yield at every one of the 13 locations. The mean response to 6 tons per acre slaked lime in the absence of nitrogen was 920 lb. paddy per acre. The response to nitrogen in the absence of lime was a non-significant increase of 142 lb. paddy per acre. The lime plus nitrogen treatment was highly significantly better than the control (L_0N_0) but highly significantly inferior to the lime-only treatment (L_1N_0) owing to a severe lime and nitrogen interaction.

The same trial on a similar soil type in Kamburupitiya Range gave the results shown in Table V.

TABLE V

Individual plot yields of paddy (lb./acre), Kamburupitiya Range

Location	L_0N_0	L_1N_0	L_0N_1	L_1N_1	*S. E.*
1 ..	1,922 ..	2,121 ..	2,090 ..	2,389 ..	
2 ..	1,935 ..	2,204 ..	2,066 ..	2,227 ..	
3 ..	1,590 ..	1,937 ..	1,217 ..	1,590 ..	
4 ..	1,358 ..	1,784 ..	1,314 ..	1,918 ..	
5 ..	1,672 ..	2,505 ..	1,981 ..	2,275 ..	
Mean ..	1,697	2,111	1,734	2,079 ..	79

As in the Mirigama Range, lime increased the yields over the unlimed treatment at every single location although there was hardly any response to nitrogen. There was no lime x nitrogen interaction. The mean response to 6 tons per acre slaked lime was 382 lb. per acre paddy.

These trials show that on the strongly acid lateritic soils of Mirigama and Kamburupitiya lime produced marked increases in yield while 200 lb. of ammonium sulphate per acre gave an insignificant increase in yield. The benefits of liming cannot therefore be associated with increased mineralization of organic nitrogen that liming no doubt would have brought about. The inferiority of the lime-and-nitrogen treatment (L_1N_1) to the lime alone treatment (L_1N_0) in Mirigama Range probably reflects the adverse effects of excess nitrogen.

A pH near neutrality accelerates the liberation of phosphate from organic residues just as it favours the mineralization of organic nitrogen. Increased availability of phosphate might therefore be one of the benefits of liming. This was tested in lime and phosphate trials set down on the strongly acid lateritic soils of Mirigama Range.

LIME AND PHOSPHATE TRIALS

Object : To study the response of rice to lime in the presence and absence of phosphate.

Design : 3 $\times$ 2 factorial.

Levels : Lime—0, 3, 6 tons per acre slaked lime.

Phosphate—0 and 40 lb. per acre P_2O_5 rock phosphate.

Basal dressing : 50 lb. K_2O per acre as muriate of potash.
Season : April-September, 1958.

The limed plots stood out by its dark green colour and luxuriant growth. But during this very wet season there was severe lodging and loss of crop owing to rat damage. No response was revealed to lime or P during this season.

The same experiment was continued at 10 locations in October, 1958 to March, 1959 to test residual effects of lime. No lime was applied but the phosphate and potassium dressing were given. The results are summarized in Table VI.

TABLE VI

Mean yields of Paddy in lb/acre

Rock phosphate lb./acre P_2O_5	*Slaked lime (tons/acre)*			*S. E.*
	0	*3*	*6*	
0	2,313	2,861	2,815	89
40	2,594	2,712	2,650	

There was a highly significant response to lime, a significant lime x phosphate interaction but no significant overall response to phosphate. The figures show, however, that there has been a significant response of 279 lb. paddy to 40 lb. P_2O_5 in the absence of lime while the responses to phosphate at the higher levels of lime are non significant.

A fresh 3 × 2 factorial experiment in the same season in the same Range with 0, 4 and 8 tons per acre ground coral limestone and 0 and 40 lb. P_2O_5 per acre as rock phosphate revealed highly significant responses of 460 and 657 lb. paddy per acre to 4 and 8 tons per acre ground limestone, respectively. There was no significant response to phosphate nor a significant lime x phosphate interaction.

The results are summarized in Table VII.

TABLE VII

Mean Treatment Yields in lb./acre

Rock phosphate lb./acre P_2O_5	*Ground limestone in tons per acre*			*S. E.*
	0	*4*	*8*	
0	2,073	2,473	2,703	100
40	1,911	2,412	2,596	

A form of lime trial was set down in the same Range with the following objectives : (*a*) to determine the best form of lime for this Range, and (*b*) to elucidate the mechanism of the action of lime.

Slaked coral lime, ground coral limestone and ground dolomite at a lime equivalent of 6 tons per acre slaked lime were tested at 14 locations in the Mirigama Range over a basal dressing of 40 lb. P_2O_5 per acre as rock phosphate and 50 lb. K_2O per acre as muriate of potash, during the season October, 1958-March, 1959.

The mean yields in lb. per acre are shown below—

No. lime	*Slaked coral lime*	*Ground coral limestone*	*Ground dolomite*	*S. E.*
2,445 ..	3,151 ..	2,930 ..	2,764 ..	72

The responses to slaked coral lime, ground coral limestone and dolomite were 707, 486 and 319 lb. of paddy per acre respectively. All these forms of lime gave highly significant increases in yield. Slaked lime was significantly superior to both ground coral limestone and ground dolomite. Ground coral limestone was better than ground dolomite. The superiority of slaked lime to the ground carbonate forms is no doubt due to its strong chemical nature and the extreme fineness of the particles. It could also be due to the peptizing action of slaked lime on soil organic matter on which Japanese workers (3) lay so much emphasis. But that this effect is relatively unimportant may be inferred from the fact that even in the fourth season from the first slaked lime application the response to the first lime application remains undiminished.

LEVELS OF LIME

The rate of liming should vary with (*a*) and pH, (*b*) the clay content, and (*c*) the organic matter content of the soil. The optimum lime dressing will, therefore, have to be determined for each soil type. This is being done.

The results available so far suggest that, generally speaking, a dressing of 5-8 tons per acre ground coral limestone is necessary on the strongly acid clay loam of the low country wet zone for a response of the order of 500 lb. paddy per acre. On the less strongly acid loams of the mid country wet zone adressing of 2.7 tons per acre ground limestone produced the same response.

MECHANISM OF THE ACTION OF LIME

The increase in yield brought about by the application of lime to acid lateritic soils may provisionally be attributed to :

(i) decrease in concentration of ferrous iron in the soil solution ;

(ii) decrease in the concentration of organic acids formed during the anaerobic decomposition of organic matter ;

(iii) decrease in concentration of CO_2 ;

(iv) increased supply of Ca and Mg ;

(v) increased supply of N and P ;

(vi) increased absorption of N by rice roots ;

(vii) increased availability of silica and Molybdenum ;

(viii) improvement in physical condition of soil.

Decrease in Concentration of Fe+². Although a pH near neutrality favours the reduction process in a submerged soil, it prevents the build up of a high concentration of ferrous iron. This is shown in Table VIII.

TABLE VIII

Changes in Concentration of Fe+² in the Soil Solution from a submerged Acid Lateritic Soil

Days from submergence		*0*	*30*	*60*	*90*	*120*
Slaked lime (tons/acre)	*pH*	*Fe+² in ppm*				
0	4·4	0·3	7·3	40	122	243
3	5·9	0·3	0·5	37	48	80
6	6·7	0·3	0·3	32	26	45

Excess iron is toxic to rice (1). The decrease in concentration of ferrous iron is one of the benefits of liming.

Decrease in Concentration of Organic Acids. It is not known to what extent organic acids present in the soil inhibit growth. But in solution culture certain organic acids are known to be injurious to rice (6).

A high pH favours the destruction of organic acids with the formation of CH_4 and CO_2 (7).

Decrease in Concentration of CO_2. A decrease in concentration of CO_2 is favourable to the growth of rice because CO_2 in concentrations exceeding 15 per cent is toxic to rice (4, 5). The decrease in concentration of CO_2 may be attributed to (i) the diluting effect of CH_4 from the decomposition of organic acids at high pH, and (ii) to the lowering of the concentration of the species "H_2CO_3" at high pH values, according to the equilibria,

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^1$$
$$HCO^1_3 \rightleftharpoons H^+ + CO_3^{11}$$

Increased Supply of Ca and Mg. This is probably one of the chief benefits of liming, for strongly acid lateritic soils are extremely deficient in bases. A dressing of 6 tons of slaked coral lime per acre supplies approximately 9,500 lb. Ca and 200 lb. Mg O per acre.

Increased Supply of N and P. Lime accelerates the mineralization of organic nitrogen and phosperous under anaerobic conditions because a pH near neutrality favours the activity of anaerobic bacteria. The peptizing action of a high pH on soil organic matter is another reason advanced by Japanese workers, (3) for the benefits of liming. This explanation, however, does not account for, (*a*) the long term effects of lime, and (*b*) the effect of carbonate forms of lime.

Increased Absorption of N by Rice Roots. A high pH favours the absorption of nitrogen as ammonia because the protoplasmic membrane of the cells of rice roots is more permeable to the un-ionized NH_4OH molecules than to NH_4+ ions. An increase in pH favours the change.

$$NH_4^+ + OH^1 \rightarrow NH_4OH$$

Increased Availability of Silica. Lime favours the reduction of a submerged soil. As reduction proceeds silica is released (8) probably from ferri-silica complexes.

Improvement in Physical Condition. This view was commonly advanced by the farmers in whose fields liming trials were carried out. They referred to a loosening of heavy clay soils by the increased fermentation that went on in the limed plots. It may be mentioned in support of this that root system of rice plants in the limed plots was very well developed.

GENERAL SUMMARY

Liming of strongly acid lateritic soils in Ceylon has given striking increases in yield. A single six-tons-per-acre application of slaked

lime gave an increase of over 700 lb. per acre paddy for four seasons in succession on an imperfectly drained acid lateritic clay at Panagoda Rice Research Station. In cultivators' fields average responses as high as 920 lb. paddy were obtained on similar soils to lime at 6 tons per acre. Residual effects a year later were of the order of 500 lb. paddy per acre. In Mirigama Range nitrogenous and phosphatic fertilizers appeared to be superfluous in the season of liming. The responses to forms of lime at a lime equivalent of 6 tons per acre $Ca(OH)_2$ were in the following descending order : slaked coral lime, ground coral limestone, ground dolomite. The optimum level of limestone was about 6 tons per acre for the strongly acid soils of the low country wet zone and about 3 tons per acre for the less acid soils of the mid country wet zone.

LITERATURE CITED

1. *Nature* 175 : 265, 1955.
2. *Soil and Plant Food* 2 : 148—157, 1957.
3. *Inorganic Nutrition, Fertilization and Soil Amelioration of Lowland Rice*, 1954.
4. *Plant Physiology* 19 : 33—51, 1944.
5. *Plant Physiology* 20 : 221—232, 1945.
6. *Journal Science of Soil and Manure* 24 : 45—50, 1953.
7. *Biochemical Journal* 29 : 528—541, 1955.
8. *Journal of Ecology* 29 : 280—329, 1941.

FERTILIZER EXPERIMENTS IN CULTIVATORS' FIELDS IN CEYLON

F. N. Ponnamperuma
(Chemist, Department of Agriculture, Ceylon)

FERTILIZER experiments in cultivators' fields, which were begun in Ceylon in 1955, were continued on an increasing scale during the past four years. Over 12,600 experimental plots were laid down at 1,642 locations during the period October 1955 to October 1959. The scope of the experiments was increased with each successive season and to date has included the following kinds of trials :—

1. forms of nitrogen ;
2. forms of phosphate ;
3. top dressing with ammonium sulphate ;
4. N, P ;
5. complex N, P, K ;
6. simple NPK treatment comparisons ;
7. liming ;
8. trace elements ;
9. silica.

The methods and organization of the scheme of fertilizer experimentation in cultivators' fields and results up to August 1958 were published in Vol. VIII, No. 1 of the International Rice Commission News letter. This paper reports briefly the conclusions of the trials up to August 1958, and the results of the subsequent experiments up to April 1959.

1. FORMS OF NITROGEN TRIALS

1.1 October 1956–March 1957

A 3 × 3 factorial experiment replicated at 14 locations in a Range in the wet zone where the soils were imperfectly to moderately well drained strongly acid lateritic clays and loams showed that during this season :

(*a*) ammonium sulphate was superior to urea and ammonium nitrate ;

(*b*) the differences between urea and ammonium nitrate were not significant; and

(*c*) the response to nitrogen was linear in the range 0–60 lb. N per acre and averaged 9 lb. of paddy per lb. of N.

1.2 October 1957-March 1958

During this season of unusually heavy rainfall and severe floods, four-plot trials at 38 locations revealed no response to nitrogen at 40 lb. N per acre over a basal dressing of 40 lb. P_2O_5 and 50 lb. K_2O per acre nor differences among ammonium sulphate, urea, and ammonium nitrate.

1.3 October 1958–March 1959

Object : to study the response of rice to ammonium sulphate, urea, ammonium nitrate and ammonium phosphate (16-20 grade adjusted with ammonium sulphate and rock phosphate) at 40 lb. N per acre over a basal dressing of 40 lb. P_2O_5 as rock phosphate and 50 lb. K_2O as muriate of potash.

Design : Randomized blocks of five plots replicated at several locations in each Range permitting analysis of results Rangewise or by zone.

Results :

TABLE 1·1

Mean Yields of Paddy in lb./acre

Zone	*Soils*	*No. of locations*	*Control*	*Amm. Sulph.*	*Urea*	*Amm. Nitrate*	*Amm. Phosph.*	*S.E.*
Dry zone ..	Well drained neutral, grey loams and clays	19	1,183	3,599*	3,706**	3,375	3,690**	106
			100	113	116	106	116	(%)
Mid-country wet zone	Moderately well drained brown acid loams	35	2,506	2,870*	2,700*	2,718*	2,871**	53
			100	115	108	109	115	(%)
Low-country wet zone	Imperfectly drained brown acid clays and loams	28	1,285	1,442	1,639*	1,573*	1,717*	66
			100	112	128	122	134	(%)

*Significant at 5% level.
**Significant at 1% level.

Conclusions :

Dry Zone. All nitrogenous fertilizers except ammonium nitrate gave significant increases in yield. The mean response to 40 lb. N in the form of ammonium sulphate, urea, and ammonium phosphate (among which there were no significant differences) was 482 lb. paddy per acre.

Mid Country Wet Zone. All forms of N gave significant increases in yield over the no-nitrogen control. Ammonium sulphate and ammonium phosphate significantly outyielded urea and ammonium nitrate. There was no significant difference between ammonium sulphate and ammonium phosphate nor between urea and ammonium nitrate. The mean response to 40 lb. N as ammonium sulphate and ammonium phosphate was 365 lb. paddy per acre.

Low Country Wet Zone. All forms of N except ammonium sulphate gave significant increases in yield. The mean response to 40 lb. N in the form of ammonium nitrate, urea, and ammonium phosphate was 358 lb. paddy per acre.

1.4 April–September 1959 trials

The following nitrogenous fertilizers were tested at 40 lb. N per acre over a basal dressing of 40 lb. P_2O_5 per acre as rock phosphate and 50 lb. K_2O per acre as muriate : ammonium sulphate, urea, ammonium nitrate, ammonium sulphate nitrate, and ammonium phosphate (16-20 grade adjusted with ammonium sulphate and rock phosphate). The results are shown in Table 1.2.

TABLE 1·2

Mean yields in lb./acre

Zone	*Soils*	*No. of locations*	*Control*	*Amm. sulph.*	*Urea*	*Amm. nitrate*	*Amm. Sulph. nitrate*	*Amm. Phosph.*	*S.E.*
				**	**	**	**	**	
Dry Zone ..	Grey neutral clays and loams	24	2,234	2,795	2,854	2,719	2,599	2,712	50
			100	125	128	122	116	121	(%)
		**	**	**	**	**	**	**	
Mid-Country wet zone	Brown acid loams	12	2,222	† 2,727	2,864	2,741	†2,862	† 3,012	61
			100	123	129	123	129	136	(%)
					*	*	*		
Low-country wet zone (Kalawana)	Brown strongly acid loams	6	1,207	1,312	1,440	1,531	1,581	1,679	95
			100	109	119	127	131	139	(%)

*Significant at 5% level.

**Significant at 1% level.

Conclusions :

Dry Zone. All forms of N gave significant increases in yield over the no-nitrogen treatment. Ammonium sulphate nitrate was significantly inferior to ammonium sulphate, urea, ammonium nitrate and ammonium phosphate, among which there were no significant differences. The mean response to 40 lb. N per acre in these four forms was 536 lb. of paddy per acre.

Mid Country Wet Zone. All forms of N yielded significant responses. Ammonium phosphate significantly out-yielded the others. The mean response to 40 lb. N as ammonium phosphate was 790 lb. paddy per acre.

Low Country Wet Zone. (Kalawana). All forms of N except ammonium sulphate gave significant increases in yield. The mean response to 40 lb. N as ammonium nitrate, ammonium sulphate nitrate and ammonium phosphate was 390 lb. paddy per acre.

1.5 General Conclusions :

The results of these trials show that the responses to the forms of N vary with the soil, zone, and season.

In the dry zone there were no significant differences among ammonium phosphate, urea, and ammonium sulphate ; these forms of nitrogen were superior to ammonium nitrate and ammonium sulphate nitrate. In the mid country wet zone ammonium phosphate gave a higher response than ammonium sulphate, urea, ammonium nitrate and ammonium sulphate nitrate. In the low country wet zone ammonium sulphate was inferior to the other forms of nitrogen. Ammonium phosphate appears to be the best.

The responses to 40 lb. N per acre in the presence of 40 lb. P_2O_5 and 50 lb. K_2O per acre ranged from 358-790 lb. paddy per acre.

2. FORMS OF PHOSPHATE TRIALS

2.1 April-September 1959 Trials

There were no significant differences among the phosphatic fertilizers, soft rock phosphate, ordinary superphosphate, concentrated superphosphate, basic slag and bone meal (3/32″ grade) at 40 lb. P_2O_5 per acre over a basal dressing of 200 lb. per acre ammonium sulphate and 100 lb. per acre muriate of potash. The mean responses to 40 lb. P_2O_5 per acre was 501 lb. per acre paddy.

The soils in six of the eight locations at which this experiment was carried out were well drained, neutral, non-lateritic loams.

2.2 October 1957-March 1958 Trials

The forms of phosphate trials replicated at eighty-five locations in the wet zone on acid and strongly acid moderately well drained to poor drained lateritic loams and clays revealed no significant differences among soft rock phosphate, ordinary superphosphate, concentrated superphosphate, basic slag, and bone meal.

During this season of unusually heavy rainfall the responses were significant only on the acid, moderately well drained soils of the mid country. The mean response in the mid country was 563 lb. paddy per acre to 40 lb. P_2O_5 per acre.

3. TOP DRESSING TRIALS WITH AMMONIUM SULPHATE

Top dressing alone with ammonium sulphate 30 days before heading of the relatively productive well drained, neutral, non-lateritic clays and loams under the major Irrigation Schemes at eighteen locations in the dry zone gave a mean response of 543 lb. paddy per acre to 100 lb. ammonium sulphate and a further increase of 229 lb. per acre to 200 lb. ammonium sulphate per acre.

These trials were carried out during the season April-August 1957.

4. N, P TRIALS

4.1 April–September 1957 Trials

The responses of rice to 0, 40, 80 lb. N per acre as ammonium sulphate and 0 and 40 lb. P_2O_5 per acre as concentrated superphosphate over a basal dressing of 100 lb. per acre muriate of potash was studied in a 3 × 2 factorial experiment replicated at eight locations on neutral non-lateritic loams in the dry zone.

The average responses were 327 lb. paddy per acre to 40 lb. N per acre, and a further 200 lb. of paddy to 80 lb. N per acre. The average response to 40 lb. P_2O_5 per acre was 322 lb. paddy per acre.

4.2 October 1957–March 1959 Trials

The same trial was laid down at fifty six locations on acid to strongly acid lateritic soils in ten districts in the wet zone.

During this season of exceptionally heavy rainfall the response to nitrogen was not significant in any of the ten districts. The response to 40 lb. P_2O_5 per acre was significant only in the mid country, as in the form of phosphate of the same season, and averaged 506 lb. paddy per acre.

5. COMPLEX N, P, K TRIALS

These trials were set down to determine the optimum combination of N, P, K for each District and, if possible, for each Range.

The levels were :

N—0, 30, 60 lb. N per acre as ammonium sulphate
P—0, 20, 40 lb. P_2O_5 per acre as rock phosphate
K—0, 50 lb. K_2O per acre as muriate of potash.

The response of rice to 14 of the 18 possible combinations of N, P, K were studied in 5 " blocks " of 6 plots each set down at random within each Range. The results are summarized in Table 5.1.

TABLE 5·1

Results of Yala 1958 N, P, K Trials

District	*No. of "blocks" (locations)*	*Control lb. acre*	*Mean responses in lb. per acre to*					Optimum combination
			N_1	N_2	P_1	P_2	K_1	
			**	**	*	**		
Kandy ..	25 ..	1,726	417	418	185	355	121	N_1P_2
Kegalle ..	15 ..	1,741	91	125	10	90	197*	K_1
Ratnapura ..	20 ..	982	207**	255**	185**	320**	35	N_1P_2
Colombo-Kalutara-Galle ..	25 ..	1,496	76	102	95	147	30	—
Kurunegala ..	15 ..	1,453	178*	202*	52	73	35	N_1
Hambantota ..	15 ..	2,198	408**	508**	248*	68	236*	N_1P_1

* Significant at 5% level.

** Significant at 1% level.

6. SIMPLE N, P, K TRIALS

The complex N, P, K trials of the proceeding section imposed a heavy burden on the Range Officers. Besides, the loss of even a block through flood, drought, insect or cattle damage made the statistical analysis difficult and also detracted considerably from the value of the experiment. The N, P, K trials were therefore simplified to a test of eight or nine combinations of three levels of N and P, and two of K. These treatment combinations were based on the observations that: (i) Ceylon rice soils generally respond to both N & P ; (ii) the optimum combination of levels of N & P varies with the zone and soil type ; and (iii) potassium is relatively unimportant on most rice soils of Ceylon.

6.1 Simple —Plot N, P, K Trials

Design : Randomized block of 8 plots replicated at locations.

Treatments : (1) Control (no fertilizers) ; (2) N_1P_1 ; (3) $N_1P_1K_1$; (4) N_1P_2 ; (5) N_2P_1 ; (6) $N_2P_1K_1$; (7) N_2P_2 ; (8) $N_2P_2K_1$.

N_1 = 30 lb. N per acre as ammonium sulphate
N_2 = 60 lb. N per acre as ammonium sulphate
P_1 = 20 lb. P_2O_5 per acre as rock phosphate
P_2 = 40 lb. P_2O_5 per acre as rock phosphate
K_1 = 50 lb. K_2O per acre as muriate of potash

Season : October 1958–March 1959

Results :

TABLE 6·1

Mean yields of Paddy in lb./acre

Zone	*Soils*	*Locations*	*Control*	N_1P_1	$N_1P_1K_1$	N_1P_2	N_2P_1	$N_2P_1K_1$	N_2P_2	$N_2P_2K_1$	*S.E*
				**	**	**	**	**	**	**	
Dry Zone	Grey neutral clays and loams	18	2,909	3,432	3,381	3,483	3,335	3,330	3,082	3,482	86
				**	**	**	**	**	**	**	
Mid-country wet zone	Brown acid loams ..	15	2,145	2,566	2,714	2,682	2,837	2,836	2,717	2,532	69
				*	*	*	*	*	*	*	
Low-country wet zone	Brown strongly acid clays and loams	15	1,224	1,581	1,558	1,748	1,577	1,563	1,512	1,640	74

Conclusions :

DRY ZONE NEUTRAL GREY LOAMS & CLAYS. All treatments except N_2P_5 gave highly significant increases in yield over the unfertilized control. N_1P_1 gave a highly significant increase of 521 lb. paddy per acre or 18 per cent over the control.

MID COUNTRY WET ZONE BROWN, ACID LOAM. All treatments gave highly significant increases in yield over the unfertilized control. N_2P_1 gave an increase of 694 lb. paddy per acre or 32 per cent over the control.

LOW COUNTRY WET ZONE. All treatments gave significant increases in yield. N_1P_1 gave an increase of 357 lb. paddy per acre or 29 per cent over the unfertilized control.

6.2 Simple 9—Plot N, P, K Trials

These trials were similar to those of the preceding section except that an additional treatment, viz, $N_1P_2K_1$, was included. The levels of N, P, & K were the same as in 6.1.

Design : Randomized blocks of 9 plots replicated 6 times in each Range.

Season : April–September 1959.

Results :

TABLE 6·2

Mean Yields of Paddy in lb./acre

Range	*Control*	*N P* 1 1	*N P* 1 1 *K* 1	*N P* 1 2	*N P* 1 2 *K* 1	*N P* 2 1	*N P* 2 1 *K* 1	*N P* 2 2	*N P* 2 2 *K* 1	*S.E.*
1. Hambantota ..	3,729	4,382**	3,918**	4,189**	4,337	3,937	3,768	4,128**	3,860	109
2. Hungama	1,509	2,071**	2,119**	1,902	2,163**	2,199**	2,270**	2,388**	2,203**	139
3. Beliatta..	2,292	2,681**	2,659**	2,659**	2,680**	2,731**	2,689**	2,719**	2,793**	78
4. Embilipitiya..	2,502	3,084*	2,930	3,288**	2,976*	3,320**	3,081*	3,359**	3,531**	172
5. Talpotha..	3,416	3,796	3,806	3,798	3,612	4,039	3,387	3,672	3,506	185
6. Killinochi..	1,299	2,682**	1,911**	2,453**	2,434**	3,052**	3,061**	2,189**	2,467**	150
7. Matale South	2,621	3,325	3,135	3,086	3,213	2,953	3,169	3,087	3,201	137
8. Tumpana	2,665	2,816	2,781	2,874	2,739	2,908	2,697	2,779	2,615	51
9. Yati-Nuwara-Udu-Nuwara	1,473	1,819	2,610	1,976	2,102	1,923	2,190	2,047	2,156	197
10. Patadumbara ..	2,958	3,482	3,548	3,416	3,331	3,469	3,365	4,191*	3,868	220
11. Mawanella ..	3,433	3,856	3,366	3,689	3,410	3,852	3,602	3,812	3,853	229
12. Kolonne	2,067	2,695*	2,740*	2,750*	2,293	2,487	2,388	2,706*	2,778*	210
13. Alawwa	2,556	2,596	2,840	2,906	2,864	3,093*	3,146*	2,863	2,999*	139
14. Piliyandala ..	1,296	1,464	1,745	1,394	1,676	1,474	1,425	1,484	1,315	123
15. Horana	1,528	1,681	1,844	1,748	1,738	1,873	1,790	1,688	1,720	90
16. Horagolla ..	1,721	1,907	1,897	1,937	2,138	1,775	2,070	2,177	1,994	180
17. Kalutara	1,389	1,630*	1,725*	1,726*	1,613*	1,652*	1,602*	1,567	1,684*	72
18. Matugama..	1,885	2,198*	1,914	2,078	2,299**	2,230*	2,415**	2,009	2,109	113
19. Kalawana..	1,270	1,575	1,227	1,429	1,689	1,606	1,548	1,559	1,565	152

Range No.	*Soils*
1.	Grey, neutral to slightly alkaline clays.
2.	Grey, saline, slightly alkaline clays.
3–5.	Grey, neutral loams.
6.	Grey, sandy loams.
7–12.	Brown, acid loams.
13–19.	Brown, strongly acid clay loams.

Conclusions :

TABLE 6·3

Range	Best Treatment lb./acre			Increase over control	
				lb./acre	%
	N	P_2O_5	K_2O		
1. Hambantota	30	20	—	651	17·7
2. Humgama	60	20	—	690	45·9
3. Beliatta	30	20	—	389	16·7
4. Embilipitiya	60	40	—	857	34·3
5. Talpotha	—	—	—	—	—
6. Kilinochi	60	20	—	753	57·9
7. Matale South	30	20	—	704	26·8
8. Tumpane	—	—	—	—	—
9. Yatinuwara-Udunuwara	30	20	50	1,137	77·7
10. Pata Dumbara	60	40	—	1,233	41·7
11. Mawanella	—	—	—	—	—
12. Kolonne	30	20	—	628	30·4
13. Alawwa	60	20	—	537	21·0
14. Piliyandala	—	—	—	—	—
15. Horana	—	—	—	—	—
16. Horagolla	—	—	—	—	—
17. Kalutara	30	20	—	241	17·3
18. Matugama	30	40	50	414	21·6
19. Kalawana	—	—	—	—	—

The response to fertilizers was good on the grey neutral soils of the dry zone and the brown, acid soils of the mid country wet zone ; it was poor on the brown, strongly acid soils of the low country wet-zone. There was a response to potassium in only two of the 19 Ranges.

7. LIMING TRIALS

The marked and sustained responses to lime at the Rice Research Station, Panagoda, prompted the extension of liming trials to cultivators' fields. The results are summarized below.

7.1 Lime and Nitrogen Trials (October 1957)

A 2 × 2 experiment with slaked coral lime at 0 & 6 tons per acre and N at 0 and 40 lb. per acre as ammonium sulphate over a basal dressing of 40 lb. P_2O_5 & 50 lb. K_2O per acre replicated at 13 locations on the strongly acid lateritic soils in the Mirigama Range showed that :

(i) the mean response to 6 tons per acre lime in the absence of nitrogen was 920 lb. of paddy per acre ;

3——J. N. R 18288 (7/61)

(ii) there was no response to nitrogen ; and

(iii) lime alone was better than lime with nitrogen.

The mean yields in lb./acre are given below—

L_0N_0	L_1N_0	L_0N_1	L_1N_1	*S. E.*
1,868	2,788	2,010	2,452	83

The same experiment on a similar soil type at 6 locations in Kamburupitiya Range showed a response of 382 lb. paddy per acre to 6 tons of slaked lime per acre. The mean yields were—

L_0N_0	L_1N_0	L_0N_1	L_1N_1	*S. E.*
1,697	2,111	1,734	2,079	78

7.2 Residual Effects of Lime

Repetition of the trials in Kamburupitiya during the subsequent season, i.e., April 1958, revealed a response of 486 lb. paddy per acre to 6 tons per acre lime applied in October 1957. Continuation of the Mirigama trials in October 1958 (one year after liming) revealed a significant response of 322 lb. per acre paddy to the original 6 tons per acre slaked lime. During this season the response to lime applied in October 1957 in Kamburupitiya was a non-significant (5 per cent level) increase of 280 lb. per acre paddy.

7.3 Lime and Phosphate Trials

A 3 × 2 lime and phosphate trial with lime at 0, 3, 6 tons slaked lime per acre and at 0 & 40 lb. P_2O_5 as rock phosphate in Mirigama revealed no response to lime or P during the very wet season of April–September, 1958.

Continuation of these trials at 10 locations in October, 1958 revealed a significant response of 207 lb. paddy to 3 tons per acre slaked lime but no response to phosphate on the average.

A fresh 3 × 2 experiment in October 1958 in the same Range with 0, 4 and 8 tons per acre ground coral limestone and 0 and 40 lb. per acre P_2O_5 as rock phosphate revealed responses of 460 and 657 lb. paddy per acre to 4 and 8 tons per acre ground limestone respectively. There was no response to phosphate nor a lime × phosphate interaction. The mean yields in lb/acre are shown below—

L_0P_0	L_1P_0	L_0P_1	L_1P_1	L_2P_0	L_2P_1	*S.E.*
2,074	2,473	1,9111	2,413	2,703	2,596	94

7.4 Forms of Lime Trials (October 1958)

Three forms of lime, viz., slaked coral lime, ground coral limestone and ground dolomite were tested at a lime equivalent of 6 tons per acre slaked lime in 14 locations on the strongly acid lateritic rice soils of the Mirigama Range. The responses to slaked coral lime, ground coral limestone and dolomite were 707, 486, and 319 lb. paddy per acre respectively. The mean yields are shown below—

	No lime	*Slaked coral lime*	*Ground coral limestone*	*Ground dolomite*	*S.E.*
Mean yield (lb./acre)	.. 2,445	.. 3,151**	.. 2,930**	.. 2,764**	.. 72

7.5 Levels of Lime Trials

Four levels of lime, viz., 0, 2.7, 5.4, and 8.1 tons per acre ground limestone were tested in several ranges in October 1958-March 1959. The results are summarized district-wise in Table 7.1.

TABLE 7·1

Mean Yields of Paddy in lb./acre

District	*No. of locations*	*Ground limestones in tons/acre*				*S.E.*	*Optimum lime level tons/acre*	*Response lb./acre*
		0	2·7	5·4	8·1			
Kandy ..	25	2,189	2,723**	2,856**	2,992**	103	2·7	534
Kegalle ..	14	2,916	3,236*	3,281*	3,280*	90	2·7	320
Ratnapura ..	14	1,780	2,104	2,115	2,328*	145	8·1	548
Colombo ..	17	1,503	1,726*	1,850**	1,957**	54	5·4	347
Kalutara ..	15	1,390	1,594	1,565	1,594	76	—	—

Conclusions :

The response to lime was highest on the strongly acid lateritic soils of Mirigama. Here slaked lime at 6 tons per acre gave an increase of 920 lb. paddy per acre. The residual effect of lime one year later averaged 322 lb. paddy per acre.

In Mirigama Range both nitrogen and phosphatic fertilizers appeared to be superfluous in the season of liming.

The response to lime was variable. It was most marked on the strongly acid soils of Mirigama Range appreciable in the mid country and least in the Kalutara District. The responses were linear in the range 0–8.1 tons per acre ground limestone on the strongly acid soils of Mirigama, and Colombo and Ratnapura Districts. It was quadratic in this range in the less strongly acid soils of Kandy and Kegalla Districts. In the last two districts the optimum level was 2.7 tons per acre ground limestone.

8. TRACE ELEMENT TRIALS

Object : To study the response of rice to all and each of four trace elements in the presence of the others over a basal dressing of 40 lb. N, 40 lb. P_2O_5 and 50 lb. K_2O per acre.

Design : Randomized block of 6 plots replicated at six random locations in each Range.

Treatments :

1. Control (no trace elements)
2. All four trace elements (Cu, B, Zn, Mo) *
3. Minus Cu
4. Minus B
5. Minus Zn
6. Minus Mo

Rates : Cu=10 lb. per acre copper sulphate.
B =10 lb. per acre borax
Zn=10 lb. per acre zinc sulphate
Mo= 1 lb. per acre sodium mloybdate.

Season : April to September, 1959.

Results :

TABLE 8·1

Mean Yield in lb./acre

Range	*Control*	*All*	*Minus*			*Minus*	*S. E.*
			Cu	*B*	*Zn*	*Mo*	
Kosgama	1,723	1,722	1,548	1,676	1,687	1,588	139
Piliyandala	2,089	2,492*	2,326	2,364	2,582*	2,438*	109
Kolonne	2,496	2,889	2,440	2,579	2,681	2,502	130
Hambantota	3,394	3,936*	3,095	4,229**	3,068	3,447	190

Conclusions :

KOSGAMA. There was no response to trace elements.

PILIYANDALA. The pattern of yields suggests that the significant responses are to Cu and B.

KOLONNE. There is an appreciable though non-significant (5 per cent level) response to the four element treatment. There is a suggestion of the need for Cu.

HAMBANTOTA. There is a highly significant response to the combination of Cu, Zn, Mo. The pattern of responses points to a depressing effect of B. On these alkaline clays the level of boron may already be too high.

9. SILICA TRIALS

The low country wet zone strongly acid lateritic soils are deficient in silica. Silica trials were therefore set down in seven Ranges in October, 1959 in the wet zone. Silica was supplied in the form of Portland cement. Field observations suggest a marked response to silica. The trials are in progress.

10. GENERAL SUMMARY AND DISCUSSION

Fertilizer trials in cultivators' fields in Ceylon have yielded useful results.

They have shown that :

(i) ammonium sulphate, urea and ammonium phosphate are equally good sources of nitrogen on the grey non-lateritic soils of the dry zone ;

(ii) ammonium phosphate is the best form of nitrogen on the brown acid and strongly acid lateritic soils of the wet zone ;

(iii) there are no significant differences among concentrated superphosphate, ordinary superphosphate, rock phosphate, basic slag, and bone meal ;

(iv) the response to 40 lb. N in the presence of 40 lb. P_2O_5 and 50 lb. K_2O per acre ranged from 358–790 lb. paddy per acre ;

4—J N. R 18288 (7/61).

(v) the optimum combination of fertilizers under current conditions are 30–60 lb. N and 20 lb. P_2O_5 for the grey non-lateritic soils of the dry zone, 30–60 lb. N and 40 lb. P_2O_5 for the brown acid lateritic soils of the mid-country wet zone, and 30 lb. N and 20 lb. P_2O_5 on the strongly acid lateritic soils of the low country wet zone ;

(vi) responses to potassium at 50 lb. K_2O per acre are rare ;

(vii) there is a marked response to lime on certain strongly acid lateritic soils of the low country and the acid lateritic soils of the mid-country wet zone.

The responses to fertilizers were highest in the dry zone and mid-country wet zone and least in the low-country wet zone. The yields in the dry zone and mid-country wet zone would undoubtedly have been considerably higher had good seed and improved cultural practices been uniformly used.

These trials have also indicated the areas where limiting factors such as lack of water control, adverse weather, and unfavourable soil conditions preclude high yields.

The demonstration value of the trials is attested by the interest taken by the cultivators in these trials, the clamour on the part of cultivators for the siting of the experiments in their fields and the numerous inquiries from those who had seen roadside plots.

CHARACTERISTICS OF AN ILL-DRAINED RICE SOIL PROFILE IN BOMBUWELA

MERVYN W. THENABADU
(Division of Botany, Department of Agriculture, Ceylon)

INTRODUCTION

IN a survey of the rice soils of Hewagam Korale situated in the flood plain of the Kelani Ganga it was observed that the imperfectly drained Panagoda series was predominant. (4) Further south in the Kalutara District very poor drainage has resulted in large tracts of ill-drained humic rice soils.

The soils of the Rice Research Station, Bombuwela, afford a typical example of these soils. There are, in addition to these poorly drained humic soils, sandy tracts in fields adjacent to the highland.

This area receives an annual rainfall of 100-125 inches, the greater portion of which falls from May to September and from November to December. The average yields on these soils are about 20 bushels per acre. Vermatt (6) referring to the South-Western low country wet zone of Ceylon states that " the predominant limiting factor in paddy production in this part of Ceylon is the prevalence of imperfect drainage or even the lack of any drainage, ... ".

Imperfect sub-soil drainage is invariably caused by the topography or by discontinuities in the soil profile. The accumulation of toxic substances in the soil as a result of inadequate drainage is largely responsible for the initial set back in growth and for the physiological maladies like bronzing and root-rot.

MATERIALS AND METHODS

Description of the Soils. The rice soils of Bombuwela are of locally derived alluvium, deposited over the swampy floor of the valley. In depth they vary from several feet in the lower aspects to one foot or less in the higher regions of the slope. These soils are derived from the strongly weathered acid lateritic material (pH 4.9), rich in iron, low in bases.

The fields are level to gently sloping, with a flat to concave relief. Internal drainage is impeded. The very poor permeability of the subsoil contributes to the poor internal drainage and the high water table during the greater part of the year.

A striking feature of these soils is their dark brown to black top soils with surface deposits of fine clay. The average organic matter content in the furrow horizon ranges from 5 to 10 per cent. In areas of very poor drainage where the top soil assumes a spongy texture the organic matter content may be as high as 15 per cent.

Below this is a relatively hard and compacted horizon. It varies from 4 to 10 inches in thickness, and sometimes contains more organic matter than the surface horizon. In many respects this region resembles a plow-sole.

Further down the profile at about 15 inches is a horizon of sandy clay which is distinctly lighter in colour due to its lower organic matter.

Below 25-30 inches is the heavy grayish white kaolinitic clay. This layer of very sticky and plastic clay is mainly responsible for the impeded vertical drainage. A typical profile has the following characteristics :—

0–7″ Dark brown, 7.5 YR 4/2 clay (very humic) ; no mottles ; abundant organic matter ; pH 6.2.

7–12″ Very dark brown, 10 YR 2/2, clay ; compact ; weak, medium angular blocky structure, sticky when wet occasionally a few faint yellow brown mottles ; pH 5.2.

12–30″ Gray brown, 10 YR 5/2, sandy clay ; clay fraction decreases, and coarse sand fraction increases with depth ; no mottles ; pH 5.7.

30–36″ Light gray, 2.5 Y 7/2, Kaolintic clay ; very sticky and plastic ; no mottles ; pH 5.3.

The horizons were differentiated on the basis of their colour, texture, and degree of compactness. Munsell colour notations described are for the dry soil. Results of the chemical analysis of soil samples collected from the various horizons of a typical profile are set out in Table I.

A variation of this typical profile is found in some of the very boggy areas where organic matter accumulates at a depth of about 16 inches. This may prabably be due to the existence of a buried " A "

horizon owing to the cumulative origin of the soil or due to a modification of the horizon corresponding to the plow-sole. The characteristics of such a profile are as follows :—

0-7 in. Dark gray, 10 YR 4/1 clay (humic) ; no mottles ; abundant organic matter ; pH 5.9.

7-16 in. Very dark gray brown, 10 YR 3/2, clay ; compact ; no mottles ; weak, medium, angular blocky structure ; rich in organic matter ; pH 5.3.

16-31 in. Black, 2.5 Y 2/0, clay ; very compact and hard ; moderate ; medium, angular blocky structure ; sticky when wet ; abundant organic matter (presence of decaying plant material) ; no mottles ; pH 6.0.

31-39 in. Gray brown, 10 YR 5/2, sandy loam no mottles ; pH 6.1.

39-70 in. Gray 10 YR 6/1, Kaolinitic clay ; very sticky and plastic no mottles, hard when dry. Results of the Chemical analysis are shown in Table I.

Analytical Procedure. The pH and ferrous iron content were determined on the fresh soil from the field. The other determinations were done on air dried soil, passed through a 2 mm sieve. pH values were obtained using a glass electrode with a soil/water ratio of 1 : 1.

Nitrogen was determined by the Kjeldahl method. Available phosphorous was extracted according to Truog (5) and estimated by the molybdenum blue method. Exchangeable potassium was extracted with normal ammonium acetate solution and determined on the flame photometer.

The organic matter content was determined by the method of Walkley and Black (7).

Total iron, manganese and potassium were extracted with constant boiling hydrochloric acid (Hall's Method) (3). Iron was determined using o–phenanthroline according to Fortune and Mellon (1) and manganese by the periodate method, following Willard and Greathouse (8) (2).

Ferrous iron was extracted with Morgan's solution and determined using o–phenanthroline after addition of hydroxylamine. It was assumed that iron extracted by Morgan's reagent from fresh soil samples was mainly in the ferrous condition.

DISCUSSION OF RESULTS

THE water table has a marked influence on the profile characteristics. The high water-table and the consequent lack of aeration retard the biochemical process that effect decomposition of buried plants and plant residues.

The prevailing anerobic conditions restrict the oxidative processes of the micro-organisms. The result is the accumulation of organic matter.

The surface horizons are in a highly reduced state. Reddish brown rusty mottles of iron oxide frequently seen along the root channels and cracks in the well drained rice soils, are absent or are only occasionally present. Measurements of the oxidation reduction potentials have confirmed this view.

An interesting feature of these soils is that they are never very acid in spite of their very high organic matter content and the acidic and base deficient properties of the parent material. Measurements of pH of the fresh soil from the furrow slice gives values between 5.8 and 6.6. In the region of the plow-sole the soils tend to be more acid.

The soils are well supplied with nitrogen and fairly well supplied with phosphorous. The potassium content is however low.

The distribution of iron in the profile does not indicate any accumulation below the plow-sole as in the case of a well drained soil. The non-receding water table probably minimises the eluviation of iron, which is being constantly added to the surface from the adjacent ferruginous laterite highland. The content of F_2O_3 in the surface horizons usually vary between 4 and 7 percent. However in the basin shaped depressions (of relatively poorer drainage) the F_2O_3 content may be as high as 12 percent.

The distribution of manganese in the profile indicates a tendency for accumulation with depth. The manganese brought into solution after inundation is deposited in the relatively more oxidised regions at the lower depths and remain undisturbed, by subsequent plowing operations. The manganese content in these soils is generally low.

ACKNOWLEDGMENTS

Grateful acknowledgment is due to Dr. C. R. Panabokke for the invaluable guidance and advice ; and to Dr. L. H. Fernando for continued interest in this work, stimulating suggestions and encouragement.

Thanks are due to Staff of the Rice Research Station, Bombuwela, for help in the field ; and the staff of the Division of Land Use, and Division of Botany for help in the Chemical Analysis.

REFERENCES

1. Fortune, W. B. and Mellon, M. G., 1938 Determination of iron with o-phenanthroline.

2. Peech, M. Alexander, L. T. and Dean, L. A., 1947. Methods of soil analysis for soil-fertility investigations. *U. S. D. A. Circular No. 757.*

3. Piper, C. S., Soil and Plant Analysis, Waite Agricultural Research Institute, University of Adelaide.

4. Thenabadu, W. M., Gunasekera, B. C. G., and Fernando, B. L., 1958. Preliminary Report on the Survey of the Paddy Soils of Hewagam Korale. Proc : Ceylon Association for the Advancement of Science. Sect. B.

5. Truog, E., 1930. The determination of the readily available phosphorus of soils, *J. Amer. Soc. of Agron : 22 ; 874–882.*

6. Vermaat, J. G., 1956. Report on Soil and Paddy Problems in Ceylon Government Publications Bureau, Colombo. *Sessional Paper XIX.*

7. Walkely, A. and Black, I. A., 1934. An examination of the Detjareff Method for Determining Soil Organic matter and a proposed modification of the Chromic Acid Titration Method. *Soil Sci. 37 ; 29-38.*

8. Willard, H. H. and Greathouse, L. H., 1917. The colorimetic determination of Manganese by oxidation with periodate. *J. Amer. Chem Soc. 39 ; 2366-77.*

Table I.—Soil Analysis of a Typical Profile

	Depth Texture	*pH under field conditions*	*pH when dry*	*% organic matter*	*% Total N*	*Available P in ppm. P*	*Exch. K. in mg.³ 100g soil*	*% Total Iron as Fe_2O_3*	*% Total Mnth as Mn_3O_4*	*Ferrous Fe. in ppm.*	*% Total K.*
Profile 1	0-7″ clay ..	6·2	5·4	12·07	0·32	68	0·08	4·30	0·00078	1,590	0·068
	7-12″ compact clay ..	5·2	5·2	4·89	0·28	28	0·02	3·72	0·00013	718	0·078
	12-30 Sandy clay ..	5·7	5·3	1·38	0·06	40	0·02	3·50	0·00056	42	0·049
	30-36 Kaolinitic clay ..	5·3	4·5	1·90	0·08	148	0·25	3·44	0·00078	714	0·130
	Soil Analysis of profile from very boggy area										
Profile 2	0- 7″ clay ..	6·0	5·1	14·83	0·66	25	0·21	6·26	0·017	3,990	0·156
	7-16″ compact clay ..	5·3	5·0	4·42	0·59	35	0·10	7·45	0·018	2,758	0·136
	16-31″ clay with large black particles of deorganic matter ..	6·0	4·9	8·49	0·54	30	0·16	4·10	0·020	2,552	0·150
	31-39″ sandy loam ..	6·1	5·1	1·38	0·06	28	0·08	4·71	0·032	178	0·068
	39-70″ Kaolinitic clay ..	6·6	5·0	1·10	0·06	5	0·35	3·88	0·029	596	0·166

MICROBIAL CONTROL

1. Laboratory Tests on the Susceptibility of the Lepidopterous Pests of Cabbage in Ceylon to commercially prepared *Bacillus Thuringiensis* Berliner

Mervyn D. de Silva
(Division of Entomology, Department of Agriculture, Ceylon)

INTRODUCTION

OVER emphasis on the control of insect pests by chemicals had retarded the development of other methods of control, particularly, that based on the use of biological agents. The fact that chemical control tends to magnify the problems it contends with, has convinced many entomologists of the need to use chemicals with more caution than has been done in the past. There is a growing body of evidence that could be adduced to support this line of thought and bolster up the view that pest control be based, as far as possible, on natural controls. With an awakening of interest in biological methods of control, chemicals could be employed in such a way as to supplement rather than replace these natural controls.

At present, more highly toxic insecticides are being used in Ceylon, for the control of Cabbage pests, than for those of any other economic crop. In general, unrestricted application of insecticides induce innumerable deleterious side effects such as—

1. Causing secondary outbreaks of arthropods, other than those, against which control was originally directed.
2. Producing a rapid resurgence of treated species, which necessitates repeated application of insecticides.
3. Producing strains that are resistant to insecticides.
4. Destroying beneficial insects, for example, parasites, predators and pollinators.

Apart from the above drastic side effects, excessive treatment aggravates the problem of residues, hazards to persons, livestock and wild life subjected to contamination by drift. Toxic insecticide

residues on food are injurious to human beings, but the precise nature of the harm done is yet unknown. In Ceylon, the problem of residues on crops is even more serious, in that at present there is no legislation in force to supervise and control the use of insecticides, and run on the lines adopted by the Food and Drugs Administration, Department of Health, Education and Welfare in the United States of America.

It seems worthwhile therefore, to investigate any new material or method of control that would not induce any of the adverse effects of chemicals and which offer the possibility of reduced chemical residues.

BACTERIAL DISEASES USED IN INSECT CONTROL

The existence of bacterial diseases in insects had been known from very early times. Entomogenous bacteria pathogenic to insects have been isolated by many workers, Berliner (1911), d'Herelle (1911), Mattes (1927), Metalnikov and Chorine (1928, 1929), and Steinhaus (1941). Of these entomogenous bacteria, the spores of *Bacillus popilliae* isolated from the Japanese beetle, *Popillia japonica* (*Newman*) (Dutky, 1940) and *Bacillus thuringiensis* isolated from the Mediterranean flour moth, *Anagastra* (*Ephestia*) *Kuhniella* Zeller, are now being produced on a commercial basis.

BACILLUS THURINGIENSIS BERLINER

Bacillus thuringiensis is a rod bacteria morphologically related to a common spore-forming soil bacterium *Bacillus cereus*. However, it differs from the latter by belonging to the group that forms crystalline parasporal bodies. The pathogenicity of *Bacillus thuringiensis* appears to be connected with the protein crystal or parasporal body found in the sporangium along with the endospore. The spindle shaped crystalline inclusion which is freed from the cell with the spore persists indefinitely and is extremely toxic to the gut of the larvae.

The mode of action of *Bacillus thuringiensis* is not completely known. Although it was at first thought that the bacillus caused a septicaemia which was followed by death, more recent work by Heimpel and Angus (1959) suggests the mode of action to be much more complex.

According to these workers, there are three modes of action each related to the type of insect ingesting the spores. In type I group of suscepts, e.g., *Bombyx mori*, *Protoparce quinquemaculata* and *P.*

sexta, the insects become striken by a general paralysis on ingesting the bacillus. The toxic parasporal bodies are believed to damage the gut wall thereby producing a leakage of the alkaline gut contents into the blood. This is followed by a rise in the blood pH which induces the paralysis. In type II, *Bacillus thuringiensis* induces a general gut paralysis which stops persistalsis and consequently ingestion of more food, causing death in 2 to 4 days. *Nymphalis antiopa* and *Malacosoma disstria* fall into this category. *Anagastra kuhniella* is the sole representative of type III. In this case, the invasion of the body cavity by the vegetative cells produces a true septicaemia.

Bacillus thuringiensis is very virulent towards a number of lepidopterous insect species. With continued research, however, its host range may widen to include suscepts among the Diptera and Coleoptera. It has so far, demonstrated pathogenicity, for *Colias philodice eurytheme* Boisduval (Steinhaus, 1951) ; the imported cabbage worm, *Pieris rapae* Linnaeus and the diamond back moth, *Plutella maculipennis* Curt. (Tanada, 1956) ; the codling moth, *Carpocapsa pomella* Linnaeus (Stephens, 1952) and the horn worm, *Protoparce quinquemaculata* Haworth and *P. sexta* Johanssen (Rabb, 1957). *Bacillus thuringiensis,* however, is reported to have shown limited effectiveness in the control of the cabbage webworm, *Hellula undalis* F. and the cabbage looper, *Trichoplusia ni* Hubner (Tanada, 1956).

CABBAGE CATERPILLAR PESTS OF CEYLON

Eight species of leaf eating caterpillars have been recorded on cabbages in Ceylon, but *Plutella maculipennis Curt.* (Plates I and II) *Plusia eriosoma* Daubl, *Crocidolomia binotalis* Z. and *Hellula undalis* appear to be the four most predominant and widely spread species causing considerable damage to cabbages.

Field and Laboratory observations show that *Plutella maculipennis* is subjected to a high degree of parasitisation by the braconid wasp, *Apanteles plutellae* Kurdj. (Plate III). The latter has been recorded to possess some of the attributes that mark the efficient parasite. According to Lloyd (1940), *Apanteles plutellae* had shown considerable discrimination and frequently rejected hosts already parasitised. Another parasite, *Anilastus* species, belonging to the family Ichneumonidae was also recorded on *Plutella maculipennis.*

The cabbage looper, *Plusia eriosoma* was also observed to be effectively checked by a biological agent. In this case, the entomogenous fungus *Spicaria rileyi* (Farlow) Charles (Plate IV) belonging to the class *Deuteromycetes* was the controlling factor. Since, the fungus

was observed to be more prevalent in insect populations of high densities, it is construed, that certain of the effects of this micro-organism are dependent upon the density of the host population. Therefore, *Spicaria rileyi* acts as a density-dependent control factor.

Spicaria rileyi was also observed to be prevalent only in certain parts of the up country districts. In other words, the environmental limits of this widely distributed micro-organism was confined to narrow zones. This may be explained by the fact that the ecological niche of *Spicaria rileyi* may be so constituted that the occurrence of proper conditions of nutrition, temperature and humidity are limited. A thorough study, of the epizootiology of this disease causing fungus will however be necessary, before an evaluation of its efficiency, as a regulatory factor of insect populations, could be accurately assessed.

METHODS AND MATERIALS

The materials used in these tests were samples of commercially prepared *Bacillus thuringiensis* Berliner received from Rohm and Haas Company, Philadelphia 5, Pennsylvania. U.S.A. Their product Bakthane L-69 contains as its active ingredient 75 billion viable spores of *Bacillus thuringiensis* per gram of inert powder. Determination of potency based upon the number of viable spores per gram of dry material was not checked by germination tests.

All the test insects were field collected, obtained from the Welimada-Nuwara Eliya districts. Treated and control insects were caged separately, in sterilised glass tubes three inches long with a diameter of one inch. The test insects were innoculated with the bacterium *per os*. They were provided with four circular pieces of cabbage leaf having an approximate area of 3.142 sq. inches each. The cabbage leaves were dipped in a suspension of the pathogen one and a half hours before they were used for feeding. Four concentrations of the pathogen, 1 gram ; 0.75 ; 0.5 and 0.25 gram respectively, of the dry powder mixed with a standard quantity of wheat flour in 100 ml water was used. Larvae that had devoured the treated leaves provided at the commencement of the experiment, were supplied with fresh un-contaminated leaf thereafter. All the lavae that died during the period of observation after treatment, were examined microscopically, especially to determine if their death was caused by the pathogen. In cases of doubt, infection was confirmed by recovering the bacillus on plates of nutrient agar. Records were kept of the number of individuals that died during a period of 1–4 days and of the number of individuals parasitised.

RESULTS

The present study was confined to an evaluation of susceptibility to infection of the four most predominant species. However, a few individuals, ranging from 5 to 10 in number, of other species of caterpillars, that included *Agrotis ypsilon* Roh., *Euxoa segetum* Schiff. and *Prodenia litura*, were tested at a concentration of 0.25 gram per 100 ml water and were found to be highly susceptible.

In the first laboratory test 120 first and second instar *Plutella* larvae were tested. Sixty of these were treated and 60 were maintained as checks. The results of the test are tabulated in Table I.

Bacillus thuringiensis was found to be very virulent on the larvae, killing them within a period of 24 hours. The high incidence of deaths recorded in the controls are presumed to be due to mechanical injuries, incurred during handling and transfer into tubes. No symptoms of bacillary infection was observed in them.

In the second laboratory test, 225 fifth instar larvae of each of the three pests, *Plutella, Hellula,* and *Crocidolomia* were tested. Groups of 45 larvae of the three species were tested at each level of treatment and 45 were maintained as a check. The results of these tests are tabulated in tables II, III and IV.

The results show that the bacillus is very virulent on *Plutella* and *Crocidolomia* at all four levels of treatment. *Hellula undalis* however, seemed to be less susceptible than the other caterpillars at the lowest dosage level. Death in all three cases took place in approximately 1–3 days.

Since there was some difficulty in obtaining healthy specimens of *Plusia* from the field owing to a high incidence of infection by the fungus *Spicaria rileyi,* only 75 individuals of this species were tested. The results of this test, tabulated in Table VI, shows that *Plusia* is quite susceptible to the bacillus. In this case too, death occured in 1–3 days.

The laboratory tests seem to indicate that *Bacillus thuringiensis* is capable of bringing about a marked reduction in the larval populations of the four insect species that go to form the bulk of the "caterpillar complex" on cabbages. On the other hand, the present study has revealed that there is a certain amount of natural control of these insects by either the fungus *Spicaria* or the baconid parasite, *Apanteles plutellae.* Combination control by the two agents may be therefore possible, when *Bacillus thuringiensis* is used, in areas where the parasite or fungus is giving partial control.

In evaluating the results of control obtained with *Bacillus thuringiensis*, the nature of its action has to be considered somewhat differently from that of insecticides. Insects treated with the bacillus generally stop feeding within a few hours after ingesting the spores, but actual mortality takes place within 24 to 48 hours. The failure of the bacillus to destroy a pest species almost immediately as is the case with most insecticides, is compensated by the fact that feeding ceases within minutes of the application.

In order to demonstrate its effectiveness in slowing down feeding activity, the percentage of the foliage consummed, within a 24 hour period, by 15 individuals of *Plutella* and 15 individuals of *Plusia* from each of the four levels of treatment was compared with that of the controls. The results of the comparison are tabulated in Table VI.

DISCUSSION

Although, the use of pathogenic micro-organisms is still in its infancy the fact that they do not as a rule directly effect other beneficial organisms such as parasites and predators, aside from giving good control, make them very valuable weapons that could be utilised in our fight against insect competitors for the food resources of the earth. Tanada (1956) for instance, has reported that pathogenic micro-organisms, applied to crucifers, for the control of four insect pests, had no marked effect on insect parasites and predators, especially those attacking hosts other than the four insects studied. For this reason, it is believed that *Bacillus thuringiensis*, if utilised, would play an important role in future control programs.

In recent years there have been numerous examples of the adverse effects of insecticides on insect parasites and predators resulting in high host density. While, on the one hand, the use of chemicals, ignoring its impact on both beneficial and harmful insects, is shortsighted, it is unrealistic to think that biological control is a panacea for all problems of insects. A method of control, that would combine the use of chemicals and biological agents was therefore forthcoming.

Unfortunately, for a long time, these two approaches had been looked upon as two alternatives in pest control. One of the reasons for the apparent incompatibility of biological and chemical control is the failure to recognise control of insects as a complex problem in ecology (Smith and Hagen, 1959). According to these workers, chemical control and biological control can be used in a complementary manner. The ecological approach that makes full use of biological

controls, and chemicals where necessary and in a manner least distuptive to the former, has been termed Integrated control (Smith and Hagen, 1959).

The great expansion in interest in the utilisation of micro-organisms such as *Bacillus thuringiensis* opens new horizons for adopting the integrated control method which undoubtedly has enormous advantages and promise for the future. The scope for the use of micro-organisms in integrated control programs appear to have been widened in recent times with the work of Telenga (1958), in Russia who has reported that the combination sprays containing insecticides and micro-organisms gives greater control than either used alone.

SUMMARY

Plutella maculipennis Curt., *Crocidolomia binotalis Z.*, *Hellula undalis* and *Pulsia eriosoma* appear to be the four most predominant and widely spread species attacking cabbages in Ceylon.

2. *Hellula undalis*, *Crocidolomia binotalis* and particularly *Plutella maculipennis* were subjected to a high degree of parasitization by the braconid wasp, *Apanteles plutellae* not previously reported.

3. The Ichneumonid, parasite, *Anilastus* sp. was also reared from *Plutella maculipennis.*

4. *Plusia eriosoma* was found to be affectively checked by the entomogenous fungus *Spicaria rileyi.*

5. Laboratory tests show that *Bacillus thuringiensis* is very effective on the four most important species of caterpillars attacking cabbages.

6. Combination control by biological control agents and the bacillus may be possible when the micro-organism is used in areas where the parasite or fungus is giving partial control.

7. It is believed that the great expansion in interest in the utilisation of micro-organisms such as *Bacillus thuringiensis* would open new horizons for adopting the integrated method of control.

ACKNOWLEDGMENT

The author wishes to thank Mr. C. Wijeyaratnam, Laboratory Assistant in the Division of Entomology, who had been of service in many ways.

BIBLIOGRAPHY

BERLINER, E.—1911. uber die Schlaffsucht der Mehlmottenraupe Ztschr. F. das Gesam, Getreidewesen, 3 : 63-70.

CHORINE, V. —1929. New bacteria pathogenic to the larvae of *Pyrausta nubilalis* Hbn. International Corn Borer Invest., *Sci. Rpts.*, 2 : 39-53.

D'HERELLE, F.—1911. Sur une épizootie de nature bactérienne sévissant sur les sauterelles au Mexique *Acad. des Sci. Compt. Rend.*, 152 : *1413-1415.*

DUTKY, S. R.—1940. Two new spore-forming bacteria causing milky diseases of Japanese beetle larvae. *Jour. Agr. Res. 67 : 57-68.*

HEIMPEL, A. M. AND T. A. ANGUS—1959. The site of action of crystalliferous bacteria in Lepidoptera larvae. *Jour. Insect Path, 1 : 152-170.*

LLOYD, D. C.—1940.—Host selection by hymenopterous parasites of the moth, *Plutella maculipennis* Curt. *Royal Soc. Proc., B128 : 451-84.*

1942. Further experiments on host selection by the hymenopeterous parasites of the moth, *P. maculipennis. Rev. Cand. Biol., 1 : 633-45.*

MATTES, O.—1927. Parasitäre Krankheiten der Mehlmottenlarven und Versuche über ihre Verwendbarkeit als biologische Bekämpfungsmittel (Zugleich ein Beitrag zur Zytologieder Bakterien.) Gesell. F. Beförd. Gesam Naturw. Sitzber. *Marburg., 62 : 381-417.*

METALKINOV, S.—1928. The infectious diseases of *Pyrausta nulilalis* Hbn. International Corn Borer Invest., *Sci Rpts., 1: 41-69.*

RABB, *R. L., E. A.* STEINHAUS AND F. E. GUTHRIE—1957. Preliminary tests using *Bacillus thuringiensis* B. Against Hornworms. *Jour Eco. Ent., 50 (3) : 259-262.*

SMITH, R. F. AND KENNETH S. HAGEN—1959. Integrated Control Programs in the future of Biological Control. *Jour. Eco Ent., 52 (6) : 1106-1108.*

STEINHAUS, E. A.—1941. A study of the bacteria associated with thirty species of insects. *Jour. Bacteriol., 42 : 757-790.*

1951. Possible use of *Bacillus thuringiensis as* aid in biological control of the alfalfa caterpillar. *Hilgardia, 20 : 359-81.*

TANADA, Y.—1956. Microbial Control of some Lepidopterous pests of crucifers. *Jour. Eco. Ent., 49 (3) : 320-9.*

TELENGA, N. A.—1958. Biological methods of pest control in crops and forest plants in the U. S. S. R., IXth Internl. Conf. on quarantine and plant protection against pests and diseases, Moscow, Aug. 1958 : 1-15.

TABLE I

Susceptibility of 1st and 2nd instar larvae of *Plutella* to infection by *B. thuringiensis*

Dosage (grams of Bakthane L-69/ 100 ml. water)	*Number tested*	*Killed by bacillus*		*Parasitised*		*% alive at the end of two weeks*
		No.	*%*	*No.*	*%*	
1 gram	15	15	100	0	0	0
0·75 gram	15	15	100	0	0	0
0·50 gram	15	14	93·3	0	0	0
0·25 gram	15	14	93·3	0	0	0
Control	60	6*	0	0	0	90

TABLE II

Susceptibility of 4th—5th instar larvae of *Plutella* to infection by *B. thuringiensis*

Dosage (grams of Bakthane L-69/ 100 ml. water)	*Number tested*	*Killed by bacillus*		*Parasitised*		*% alive at the end of two weeks*
		No.	*%*	*No.*	*%*	
1 gram	45	30	66·7	15	33·3	0
0·75 gram	45	31	68·9	13	28·7	2·2
0·50 gram	45	32	71·1	7	15·6	13·3
0·25 gram	45	36	80·0	4	8·9	11·1
Control	45	1*	0	20	44·4	53·3

*Death due to causes other than bacillary infection.

5—J. N. R 18288 (7/61).

TABLE III

Susceptibility of 4th— 5th instar larvae of *Hellula* to infection by *B. thuringiensis*

Dosage (grams of Bakthane L-69/ 100 ml. water)	*Number tested*	*Killed by bacillus*		*Parasitised*		*% alive at the end of two weeks*
		No.	*%*	*No.*	*%*	
1 gram ..	45	38	84·4	6	13·3	2·2
0·75 gram ..	45	41	91·1	2	4·4	4·4
0·50 gram ..	45	38	84·4	4	8·9	6·7
0·25 gram ..	45	29	64·4	6	13·3	22·2
Control ..	45	12*	0	2	4·4	68·9

TABLE IV

Susceptibility of 4th— 5th instar larvae of *Crovidolomia* to infection by *B. thuringiensis*

Dosage (grams of Bakthane L-69/ 100 ml. water)	*Number tested*	*Killed by bacillus*		*Parasitied*		*% alive at the end of two weeks*
		No.	*%*	*No.*	*%*	
1 gram ..	45	34	75·6	4	8·9	15·6
0·75 gram ..	45	44	97·8	1	2·2	0
0·50 gram ..	45	43	95·6	2	4·4	0
0·25 gram ..	45	40	88·9	3	6·7	4·4
Control ..	45	20*	0	4	8·9	46·7

*Death due to causes other than bacillary infection.

TABLE V

Susceptibility of 4th—5th instar larvae of *Plusia* to infection by *B. thuringiensis*

Dosage (gram of Bakthane L-69/ 100 ml. water)	*Number tested*	*Killed by bacillus*		*Parasitised*		*% alive at the end of two weeks*
		No.	*%*	*No.*	*%*	
1 gram ..	15	11	73·3	4	26·7	0
0·75 gram ..	15	12	80	3	20	0
0·50 gram ..	15	14	93·3	1	6·7	0
0·25 gram ..	15	8	53·3	7	46·7	0
Control ..	15	4*	0	11	73·3	0

*Death due to causes other than bacillary infection.

TABLE VI

Comparison of % foliage consumed during a 24-hour period by treated and untreated *Plutella* and *Plusia* larvae

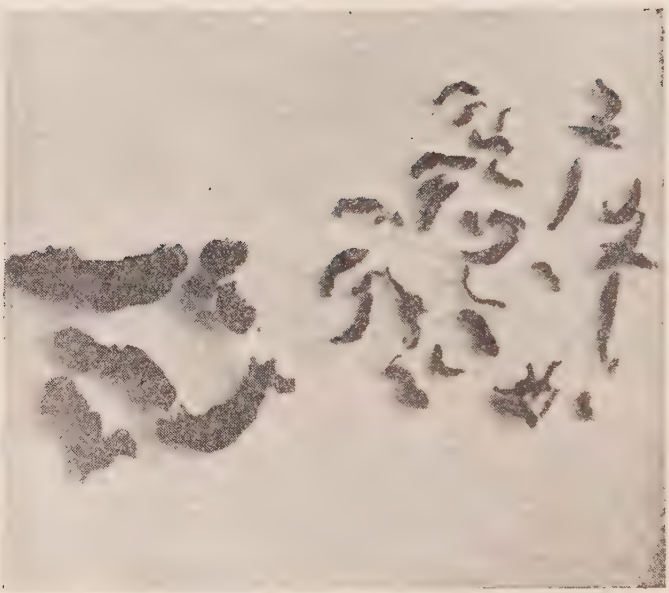
Insect	*Dosage (Grams of Bakthane L-69/100 ml. water)*	*Percentage foliage consumed*		
		Av.	*Max.*	*Min.*
Plutella ..	1	13	25	0
	0.75	13	50	0
	0.50	15	70	0
	0.25	30	50	0
	Control	30	50	0
Plusia ..	1	13	50	0
	0.75	10	25	0
	0.50	15	60	0
	0.25	15	50	0
	Control	70	100	50

Plate II.—Shows the characteristic damage caused by the larva of *Plutella.*

Plate I.—The adult Diamond Back Moth, *Plutella maculipennis* Curt.

Plate IV.—The Cabbage looper, *Plusia eriosoma* Daubl. killed by the fungus, *Sporotrichum rileyi*.

Plate III.—The larva of *Plutella* with the attached cocoon of the parasite, *Apanteles plutellae* Kurdj., which emerged from its body (much enlarged).



Larvae of the Diamond Back Moth *Plutella maculipennis* Curt. and the Cabbage Looper, *Plusia eriosoma* Daubl. dead of infection with *Bacillus thuringiensis*.

SOME OBSERVATIONS ON THE INSECT PESTS OF DHAL *(CAJANUS CAJAN)* AND THEIR CONTROL

E. S. Thevasagayam and L. S. C. Canagasingham
(Dry Zone Research Institute, Department of Agriculture, Ceylon)

INTRODUCTION

PERENNIAL dhal varieties were introduced into Government farms about three decades ago chiefly for improving soil fertility. These varieties, although they satisfied the need, did not give good yields and their seeds were small and harvesting difficult. Therefore annual varieties, which gave better and quicker yields and which had larger and more attractive seeds were introduced about eight years ago.

During the first few years of introduction the yields obtained at the Dry Zone Research Institute at Maha Illuppallama were very satisfactory, being 1,200-1,500 pounds per acre. In subsequent years there has been a steady decline in yields and at present yields are never over 400-500 pounds per acre. At times the yields have been much lower. Large scale shedding of buds and flowers, and pods without seeds or with damaged seeds have been observed to account for loss in yields. These conditions are mainly due to attack by several insect borers.

INSECT PESTS AND NATURE OF DAMAGE

Gywala (1939) who conducted a varietal trial at the experimental station, Anuradhapura, observed that the dhal crop was damaged only by two insect pests, namely (1) the pod borer belonging to the *Agromyza* species and (2) blister beetles. He however did not consider the damage serious. Ishikura (1957) who conducted a survey at Maha Illuppallama, listed four insects that attacked buds and flowers, six* that attacked pods, and four* that attacked the leaf and stem. From the present studies conducted through three seasons at Maha Illuppallama, it has been possible to list the more prevalent pest species in their order of importance, the nature of the damage and time of appearance. Observations have also been made on their biology.

(* Three of these ten insects had not been named by Ishikura.)

The plant is free from serious damage by pests during its vegetative growth and the few insects that are found during this period are of not much consequence. Pest attack is very serious in the flowering and pod forming stages. The damage can be very heavy and there have been instances where no harvest has been possible due to severe pest attack.

The annual dhal variety yields twice, once in Maha and again in Yala, and the pests of the two seasons differ and are therefore treated separately.

PESTS OF MAHA SEASON

1. **Maruca testulalis* Gever—Bud and pod boring caterpillar.
2. *Lampides boeticus* L.—Bud and pod boring caterpillar.
3. **Heliothes armigera* Hb.—Bud and pod boring caterpillar.
4. *Mylabris pustulata* Thunb.—Flower eating beetle.
5. *Sphenarches caffer* Zell.—Bud and pod boring caterpillar.
6. *Dolichothrips varipes* Bagn.—Thrips that damage flowers.

(* Not listed by Ishikura 1957)

Maha flowering starts by about late January and may go on till early March and green pods may be found on the crop till early April. Bud and pod attacking insects therefore have food available for about three months and some of them could complete three reproductive cycles during this period. Population densities of the three major caterpillar pests for Maha season is given in Fig. 1.

1. *Maruca testulalis.*—The caterpillar of this moth is the most serious pest of early Maha, sometimes attacking as much as 50 per cent of the flowers and pods. The egg is laid on the bud and the young caterpillar on hatching bores into the unopened bud and attacks it from inside. After a few days of growth it moves out and bores into a fresh bud and so on attacking as many as 20-25 buds during its life which may take about 2-3 weeks. The bud that is eaten partly fades and drops off. The caterpillar also bores in to young pods and eats up the seeds. After finishing one seed it usually comes out and bores again to get to the next seed. One caterpillar may damage several pods during its life.

Pupation usually takes place in a cluster of dried up flowers held together by a silky secretion. Pupal stage lasts about one week.

2. *Lampides boeticus.*—The caterpillar of this blue copper butterfly damages the buds and pods in the same way as *M. testacealis.* The butterflies, which are found very commonly fritting about in and

around the crop right through the season, lay their eggs on the bud and the young greenish slug like caterpillar bores into the unopened bud and moves from bud to bud as it grows. The life cycle takes about 4-6 weeks.

The caterpillar which is fairly common on the crop during the early stages of flowering shows a sharp decline as the season progresses as shown in Fig. 1. The damage due to this pest is about 10-15 per cent. Pupation is similar to that of *M. testacealis* and the pupal stage takes about 5-7 days.

3. *Heliothes armigera.*—This is a common pest of leguminous crops in general and the caterpillar attacks buds and pods in the same way as *M. testacealis.* The greenish caterpillar is about 1½ inches long. During its life one caterpillar may damage 30-40 flower buds. Young pods are also attacked by this pest and while eating the immature seeds the posterior end of the caterpillar is seen protruding outside. The caterpillar is not common in the early part of the season but builds up, especially at the tail end of Maha season. During this period damage by *H. armigera* may be as much as 15-20 per cent.

4. *Mylabris pustulata.*—This flower eating beetle shows up in late February and persists till the flowering is over. This is not a serious pest during Maha and could easily be handpicked and destroyed, when present.

5. *Sphenarches caffer.*—The caterpillar of this plume moth is also a bud and pod borer and is found in very small numbers right through the season. When other pests are found in large numbers this is very rare.

6. *Dolichothrips varipes.*—Thrips are found in almost all buds and sometimes as many as ten or twelve may be found in each bud. Severe attack by thrips results in the drying and falling off of buds.

PESTS OF YALA SEASON

1. *Melanagromyza obtusa* Malloch—Pod borer.
2. *Mylabris pustulata* Thunb.—Flower eating beetle.
3. *Maruca testulalis* Gever—Bud and pod borer.
4. *Lampides boeticus* L.—Bud and pod borer.

1. *Melanagromyza obtusa.*—This pod boring maggot is by far the most serious pest of Yala. The fly lays its eggs through a puncture, inside the seed chamber of a young pod. The maggot that hatches out lives on the seed and eventually pupates in the seed chamber but outside the seed. During its life one maggot eats only one seed

or part of it. Often a maggot may be found in each seed chamber of the pod.

No external damage is visible on the attacked pod when green but subsequently minute holes through which adult flies had emerged may be seen. The damage due to the fly is very serious and may be even 50-75 per cent at times. Partly damaged seeds are usually subject to bacterial and fungal attacks and become entirely useless.

2. *Mylabris pustulata*.—The flower eating beetle may become a serious pest in Yala.

3 & 4. *Maruca testacealis* and *Lampides boeticus*.—These two pests which do great damage during Maha, although present never reach significant proportions. Yala flowering is normally confined to period of 3-4 weeks only, and the very warm dry climate during Yala seem to have a limiting influence on these insects.

TRIAL ON THE CONTROL OF PESTS BY INSECTICIDES

Material and Methods

A preliminary trial with six insecticides was conducted during Yala 1959 and on the results of this, a full scale trial was conducted through Maha 1959/60 and Yala 1960.

Annual dhal variety T85 was used in plots 30 ft. × 20 ft. at spacing of 3 ft. × 2 ft. The following were the insecticides tried and the doses :—

Dieldrin 20 per cent *E. C. Low—1 fl. oz. in 2 gal. water.
High—1 fl. oz. in 1 gal. water.

Dipterex 80 per cent @W. S. P. Low—0.1 oz. by wt. in 1 gal. water.
High—0.2 oz. by wt. in 1 gal. water.

Endrin 20 per cent E. C. Low—1 fl. oz. in 4 gal. water.
High—1 fl. oz. in 2 gal. water.

Gusathion 20 per cent E. C. Low—1 fl. oz. in 4 gal. water.
High—1 fl. oz. in 2 gal. water.

Malathion 50 per cent E. C. Low—1 fl. oz. in 4 gal. water.
High—1 fl. oz. in 2 gal. water.

Parathion (Folidol) 46.7 per cent E. C. Low—1 fl. oz. in 8 gal. water.
High—1 fl. oz. in 4 gal. water.

Phosdrin 24 per cent E. C. Low—1 fl. oz. in 4 gal. water.
High—1 fl. oz. in 2 gal. water.

(* E. C.—Emulsion Concentrate, @ W. S. P.—Water soluble Powder.)

There were three replications with 15 plots in each replicate. The total trial area was about 3/5 acre.

Flowering started about 11 weeks after planting when the plants were about 3½-4 ft. tall. Pest incidence was significant enough to give the first spraying when the crop was about 12 weeks old. Spraying was done by senior knapsack sprayers using a cone shaped nozzle. All insecticides used were emulsion concentrates except for water soluble dipterex.

Quantitative counts of all pests were taken weekly. For this purpose, five plants were selected at random from each plot and labelled. Attacked flowers from each of these plants were plucked and counted. The number of unattacked flowers on the plant was also counted. The caterpillars from the attacked flowers were counted by species. Similarly for pods, five other plants were fixed and similar counts taken.

The crop was sprayed five times during the Maha season according to pest incidence. Plants were sprayed in such a way that the flowers were nearly drenched. About 60-80 gallons of spray fluid was required for good coverage. Five sprayings were necessary due to unusual rains in February resulting in a second spate of flowering and a second peak in pest incidence. In normal years two to three sprayings should give adequate protection for the entire season. Two picks were taken during the season.

During Yala the crop was sprayed twice and this was sufficient for the entire season. Two picks were taken during Yala also.

Results

Maha Season.—Of the seven insecticides tried dieldrin and endrin gave the best results. The percentage flowers attacked on the fifteen selected plants from each treatment is given in Table 1 and the same for pods is given in Table 2. The percentage of flowers and pods attacked in dieldrin and endrin treated plots was always less than in the untreated plots as shown in Fig. 2.

Dieldrin at the dose of 1 fl. oz. per gallon and endrin at the dose of 1 fl. oz. in 2 gallons gave the best yields, of the insecticides tried. The yield from three 30 ft. × 20 ft. plots with dieldrin was 60 lb. and with endrin was 58.3 lb. compared with 43.8 lb. in the control. In one dieldrin treated plot the yield was 23.3 lb. which works out to about 1,691 lb. per acre compared with 1,060 lb. per acre from the untreated plots.

The total yield from the trial area was 745.2 lb. of dhal which works out to 1,200 lb. per acre. The details of the yields are given in Table 4.

Yala Season.—The major pest of the Yala season being *M. obtusa,* insecticide effectiveness differred from the Maha season. The results given in Table 3, are not very significant although malathion, phosdrin and gusathion gave better yields than the others. Yield figures are given in Table 4. The total yield from the trial area was 576.4 lb. for Yala the equivalent of 930 lb. per acre Malathion at a concentration of 1 fl. oz. in 4 gallons water gave the best yield of 42.9 lb. compared to 39.2 lb. from the untreated control.

The total yield for the two seasons from the entire area was 1321.6 lb. which works out to about 2,132 lb. per acre.

Discussion

The total yield of 2,132 lb. per acre from the entire trial area shows that treatment with insecticide significantly increases yields. This compares very favourably with yields at Maha Illuppallama which have been in the neighbourhood of 300—500 pounds per acre in the past few years. The seed weight in all the treatments has been about 65—75 per cent of the bulk pod weight and in one case it was as high as 87 per cent of bulk weight. Normally the seed weight is about 50 per cent or less of the bulk weight. This is due to heavy damage to seed by pests.

Dieldrin at a dilution of 1 fl. oz. per gallon water gave the best yield. At this dose and at the rate of about 75 gallons of spray fluid per acre the cost of insecticide application works out to about Rs. 22.50 per application. With endrin at 1 fl. oz. in two gallons water, the cost per application is about Rs. 15.75. These figures include about Rs. 5 for cost of labour. Although the plots were treated five times in the present trial during Maha due to unusual weather conditions, it would seem that in normal years three applications should suffice, with two more applications for Yala.

Pest damage on dhal is very severe during Maha as conditions seem more favourable during this period. Although heavy rains have an immediate depressing effect on pest populations, there is a quick build up soon after. Prolonged flowering, sometimes for as long as 6—8 weeks also is very conducive to pest build up. The warm dry weather of Yala months seem to exert a limiting influence on the caterpillar pests but *M. obtusa* thrives during this period.

A cultural practice that promises to be of value is one of growing dhal in association with either sorghum or maize on the same piece of land. Both crops in the association are sown together at the

appropriate time in the Maha season, the grain component being harvested in January/February and the dhal component in August. In this connection the following facts are worthy of mention :—(1) The growth of the dhal, which is suppressed during the Maha season by competition with the grain crop, is rapid during the Yala season, the main flush of flowering occurring during the dry season in July—August when insect control is easiest, (2) The yield from the grain component is not influenced by competition from the dhal, and (3) Dhal cannot be successfully established in the Yala season only. A crop association of this type can make maximum use of a piece of land. The economics of the control of insects of dhal in a sorghum/dhal association is under study at present and will form the subject of a further report.

From the present studies it is evident that pests could be controlled economically by insecticides.

Summary

Yields from annual dhal varieties, introduced into the Dry Zone about eight years ago, which had been about 1,200—1,500 lb. per acre during the first two years have dwindled to less than 500 lb. per acre in recent years. Pest damage appears to be the major cause for this condition.

From observations made at Maha Illuppallama the following major pests are listed :—

Maha Season

(1) *Maruca testulalis* Gever	Bud and pod borer.
(2) *Lampides boeticus* L. ..	Bud and pod borer.
(3) *Heliothes armigera* Hb. ..	Bud and pod borer.
(4) *Sphenarches caffer* Zell.	Bud and pod borer.
(5) *Mylabris pustulata* Thunb.	Flower eating beetle.
(6) *Dolichothrips varipes* Bagn. ..	Thrips that damage flowers.

Yala Season

(1) *Melanagromyza obtusa* Malloch ..	Pod borer.
(2) *Mylabris pustulata* Thunb.	Flower eating beetle.
(3) *Maruca testulalis* Gever	Bud and pod borer.
(4) *Lampides boeticus* L.	Bud and pod borer.

Studies have been made on the nature of damage by the pests, their seasonal prevalence and relative importance.

Trials on the control of the pests have been carried out through three seasons at Maha Illuppallama. Of the seven insecticides tried, dieldrin and endrin gave very good control of all the pests during Maha season and significantly higher yields than the untreated checks. A yield of nearly 2,132 lb. per acre have been obtained from a 3/5 acre trial area. Trials have shown that pests could be economically controlled with the use of insecticide applications with adequate increase in yields.

ACKNOWLEDGMENTS

The authors wish to thank Dr. E. Abeyratne, Head of the Institute, for his guidance in these studies, and Messrs. S. Ponniah and J. Amarasena for their assistance during the entire investigations.

LITERATURE CITED

GYWALA, P. M. (1939)—*Tropical Agriculturist,* 93 : 257—269.

ISHIKURA, H. (1957)—Report to the Government of Ceylon of Dr. H. Ishikura, the Colombo Plan Expert attached to the Entomologist of the Department of Agriculture, 15 pp.

TABLE I

Percentage buds and flowers attacked, in fifteen selected plants from each treatment, during Maha season

Treatment		*Percentage buds and flowers attacked*					
		Before treatment	*One week after each treatment*				
			1	*2*	*3*	*4*	*5*
Dieldrin	Low	27	10	10	12	5	3
	High	15	4	4	8	0	3
Dipterex	Low	13	15	8	5	2	2
	High	9	16	7	12	2	1
Endrin	Low	19	3·5	6	10	0	1
	High	9	4	5	6	2	3
Gusathion	Low	29	17	10	7	0	2
	High	26	10	7	5	0	0
Malathion	Low	19	10	5	7	0	1
	High	15	14	6	9	3	2
Parathion	Low	15	7	9	10	1	2
	High	15	9	3·5	4	1	2
Phosdrin	Low	17	11	13	7	0	2
	High	10	12	12	9	0	2
Control		21	15	24	10	5	1

TABLE 2

Percentage pods attacked by caterpillars, in fifteen selected plants from each treatment, during Maha season

Treatment		*Percentage pods attacked*											
		Weeks after each treatment											
		1		*1*		*2*		*1*		*1*		*1*	*2*
Dieldrin	Low	0		4		9		9		2		2	14
	High	0		5		7		6		3		1	5
Dipterex	Low	2		2		12		4		4		2	9
	High	0		3		8		9		4		1	5
Endrin	Low	2		4		5		5		4		0	9
	High	0		2		6		5		3		0·5	5
Gusathion	Low	6		6		8		12		5		3	6
	High	3		8		8		5		3		1	10
Malathion	Low	3		6		14		12		5		0·5	2
	High	0		7		13		10		2		0	3
Parathion	Low	1		7		10		9		6		1	4
	High	0		3		8		13		3		1	8
Phosdrin	Low	0		8		13		8		3		0	8
	High	3		15		11		6		4		1	7
Control		6		8		12		15		8		8	15

TABLE 3

Percentage pods attacked by Melanagromyza obtusa in fifteen selected plants from each treatment during Yala season

Treatment		*Percentage pods attacked*			
		Weeks after first treatment		*Weeks after second treatment*	
		1	*2*	*1*	*2*
Dieldrin	Low	8	2	8	7
	High	10	7	9	3
Dipterex	Low	5	0	7	10
	High	3	2	6	6
Endrin	Low	5	2	5	5
	High	7	7	8	3
Gusathion	Low	21	2	9	4
	High	6	4	7	6
Malathion	Low	7	1	5	6
	High	6	1	7	4
Parathion	Low	6	4	8	5
	High	12	7	5	3
Phosdrin	Low	8	5	4	8
	High	1	1	6	7
Control		20	23	14	7

TABLE 4

Dhal yields in pounds of seed obtained from 30 ft. × 20 ft. plots in three replications during Maha and Yala seasons

Treatment		*Seed weight in pounds obtained during Maha 1959-60*					*Seed weight in pounds obtained during Yala 1960*					*Total yield for Maha & Yala*	*Total yield per acre*
		Rep. 1	*Rep. 2*	*Rep. 3*	*Total*	*Yield per acre*	*Rep. 1*	*Rep. 2*	*Rep. 3*	*Total*	*Yield per acre*		
Dieldrin	Low	21·3	12·9	17·1	51·3	1,240	12·5	10·5	8·8	31·8	768	83·1	2,008
	High	23·3	19·4	17·3	60·0	1,450	13·5	9·5	13·9	36·9	892	96·9	2,342
Dipterex	Low	14·4	9·2	15·2	38·8	938	9·5	14·8	10·9	35·2	851	74·0	1,788
	High	16·2	17·3	17·1	50·6	1,223	13·1	11·6	11·6	36·3	877	86·9	2,078
Endrin	Low	17·7	17·4	17·4	52·5	1,269	16·1	7·9	9·4	33·4	807	85·9	2,076
	High	20·1	22·8	15·4	58·3	1,409	12·8	16·3	12·7	41·8	1,010	100·1	2,419
Gusathion	Low	14·1	17·7	18·9	51·0	1,232	16·0	11·7	12·4	40·1	969	91·1	2,202
	High	11·9	17·7	20·3	49·9	1,206	11·1	15·8	14·0	40·9	988	90·8	2,194
Malathion	Low	14·7	14·2	19·3	48·2	1,165	18·8	15·3	8·8	42·9	1,037	91·1	2,202
	High	13·7	17·2	17·4	48·3	1,167	12·8	17·0	11·3	41·1	993	89·4	2,160
Parathion	Low	12·6	17·4	17·3	47·3	1,143	14·1	14·1	10·5	38·7	935	86·0	2,078
	High	18·1	13·3	15·5	46·9	1,133	14·1	11·6	10·5	36·2	875	83·2	2,011
Phosdrin	Low	14·7	14·5	17·5	46·7	1,129	11·6	12·0	16·3	39·9	964	86·6	2,093
	High	17·5	13·7	20·4	51·6	1,247	16·5	14·7	10·8	42·0	1,015	93·6	2,262
Control		11·8	14·9	17·1	43·8	1,059	11·2	13·2	14·8	39·2	947	83·0	2,006
	Total	242·4	239·6	263·2	745·2	1,200	203·7	196·0	176·7	576·4	930	1,321·6	2,132

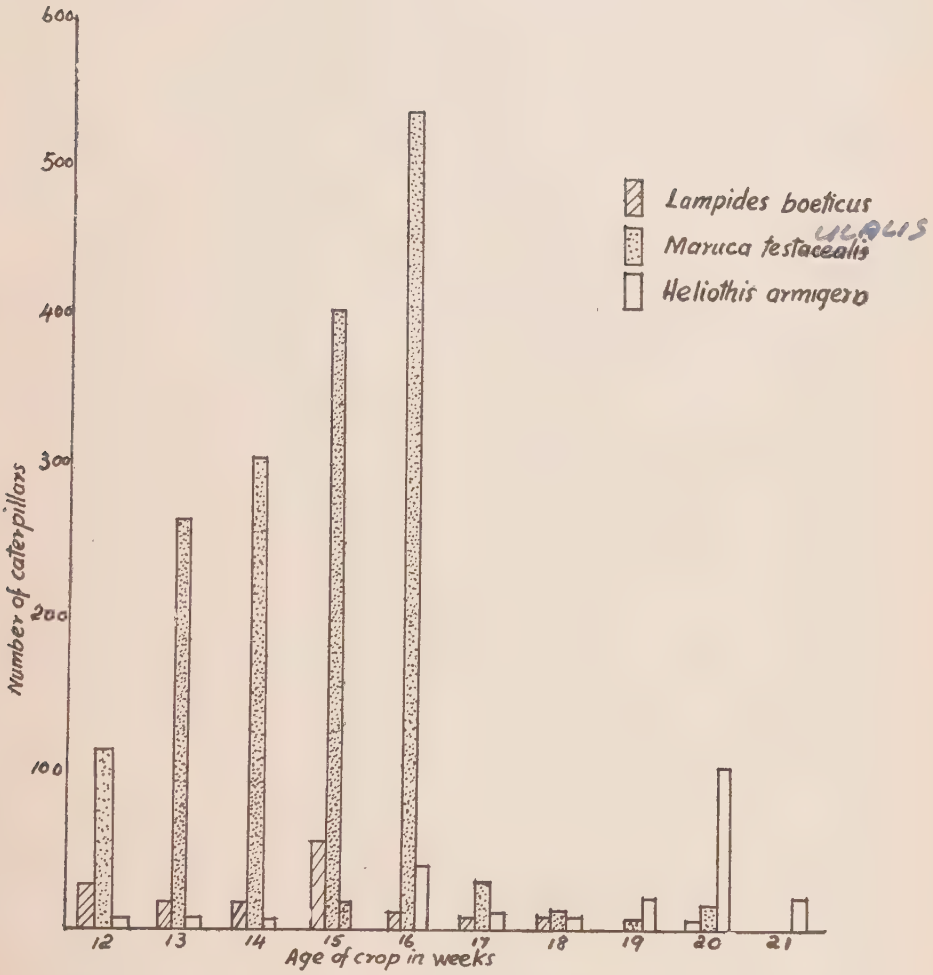


Fig. 1.—Population densitier of three major caterpillar pests on the crop during Maha season.

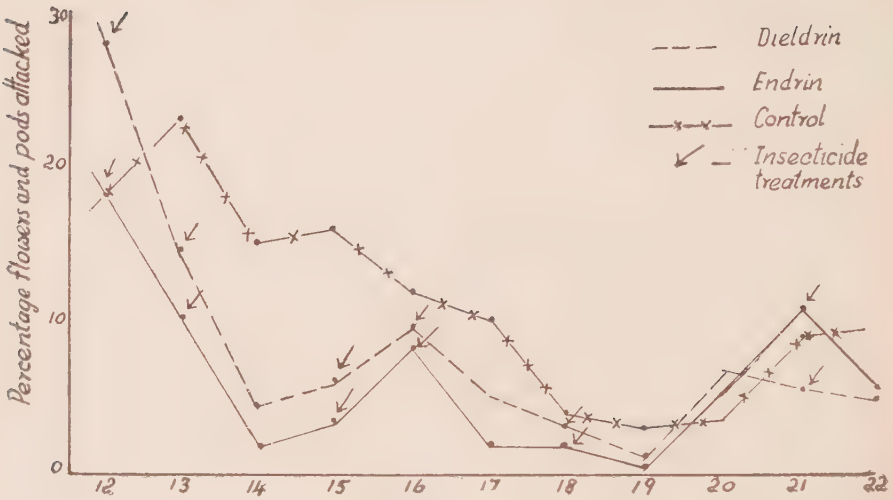


Fig. 2.—Percentage flowers and pods attacked by caterpillar pests during Maha season in the dieldrin and endrin treated plots and the untreated control.

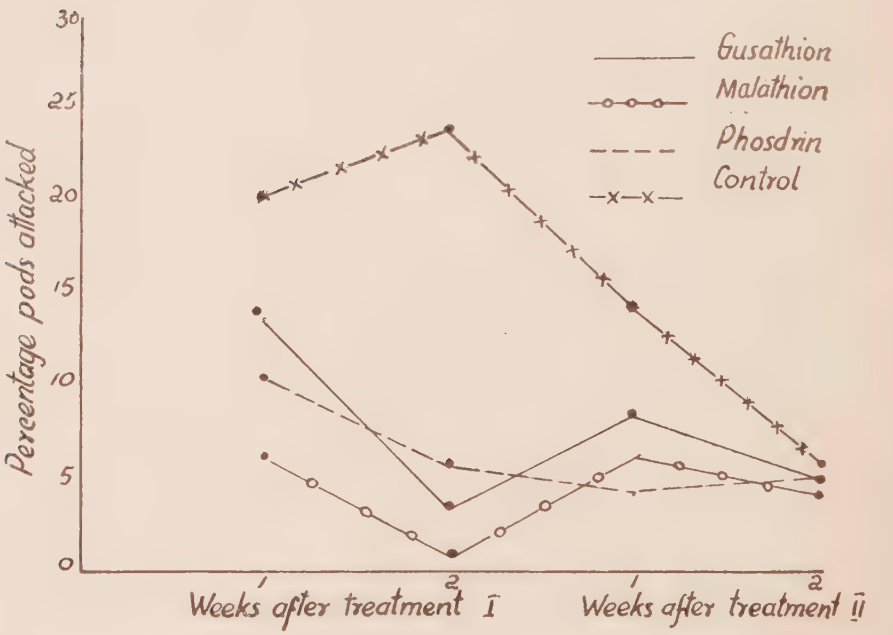


Fig. 3.—Percentage pods attacked by *Melanagromyza obtusa* during Yala season in the Gusathion, Malathion and Phosdrin treated plots and the untreated control.

PRELIMINARY STUDIES ON THE CONTROL OF INSECT PESTS OF COTTON

E. S. Thevasagayam and S. S. Mohinudeen
(Dry Zone Research Institute, Department of Agriculture, Ceylon)

INTRODUCTION

COTTON as a crop for the dry zone is gaining in importance and the need has been felt for the study of the insect pests, their importance and methods of their control. At the present time pest attack on cotton is not very severe although all known pests are observed on the crop. This is probably due to the cultivation of the crop being restricted to small localised areas. The pest situation may be different with increased cultivation of the crop.

Harbord (1937) mentions that pest incidence was low in the Hambantota District in 1937 when a yield of 10–11 cwt. per acre was obtained. There had been a minor outbreak of leaf roller which was controlled by predatory wasps. Damage by boll worm and cotton stainers was small. There is hardly any other information in the literature regarding any observations made in Ceylon on the pests of cotton.

MAJOR INSECT PESTS

From observations made during two years at the Dry Zone Research Institute, Maha Illuppallama, and the cotton growing tracts in the area, the following major pests are listed in order of their local importance :—

1. *Aphis gossypii* G.—The cotton aphid.
2. *Sylepta derogata* F.—The cotton leaf roller.
3. *Earias fabia* Cram.—The spotted boll worm.
4. *Oxycarenus latus* Kirby—The dusky cotton bug.
5. *Dysdercus similis* Freeman—The red cotton bug.
6. *Pectinophora gossypiella* Saund.—The pink boll worm.

TRIAL ON THE CONTROL OF INSECT PESTS

Materials and Methods

The trial on the control of insect pests was conducted at Maha Illuppallama, during Maha 1959-60. H. C. 101 cotton was planted at 3 ft. × 2 ft. spacing in 30 ft. × 20 ft. plots and plants thinned out to two per hill. There were three replicates and 25 plots per replication. The total trial area was about 1 acre.

The insecticides and concentrations tried are as follows :—

1. B. H. C.	20% *E. C.	Low 1† &	Low 2 —1 fl. oz. in 2 gal. water.
		High 1 &	High 2—1 fl. oz. in 1 gal. water.
2. D. D. T.	25% E. C.	Low 1 &	Low 2—1 fl. oz. in 2 gal. water.
		High 1 &	High 2—1 fl. oz. in 1 gal. water.
3. Dipterex	50% E. C.	Low 1 &	Low 2—1 fl. oz. in 6 gal. water.
		High 1 &	High 2—1 fl. oz. in 3 gal. water.
4. Endrin	20% E. C.	Low 1 &	Low 2—1 fl. oz. in 4 gal. water.
		High 1 &	High 2—1 fl. oz. in 2 gal. water.
5. §E. P. N.	25% E. C.	Low 1 &	Low 2—1 fl. oz. in 6 gal. water.
		High 1 &	High 2—1 fl. oz. in 3 gal. water.
6. Gusathion	20% E. C.	Low 1 &	Low 2—1 fl. oz. in 6 gal. water.
		High 1 &	High 2—1 fl. oz. in 3 gal. water.

(*E. C.—Emulsion concentrate).

(1†—Insecticide applied at fortnightly intervals).

(2‡—Insecticide applied according to pest incidence).

§(E. P. N.—Ethyl—p—nitrophenyl benzenethiophosphonate).

Six insecticides were used at two concentrations each. Each concentration was applied at fortnightly intervals and as and when pest incidence required. Pest incidence was such that all plots were sprayed roughly at fortnightly intervals. The crop was sprayed six times during the trial. Due to very heavy continuous rains in the early stages, the germination rate in the trial was poor. This, added to difficulties in filling vacancies and weeding, resulted in poor stands. Out of an expected 100 hills per plot there was an average of 75 hills a range of 54-95. The average number of plants per plot was 115 (Range 86–145) out of an expected 200.

Pest incidence was assessed on the basis of counts taken at fortnightly intervals. Aphid infestation was taken from 20 plants selected at random from each plot. Leaf rollers were counted from each plant in the plot. Boll worms were assessed on the basis of the number of bolls attacked on five plants selected at random and fixed.

Pest Incidence

Aphis gossypii : The cotton aphid was the most serious pest of cotton in the area. It appears when the crop is about 6 weeks old and persists right through the season. About 80-90 per cent of the plants are usually attacked. The aphid incidence in various treatments is given in Table 2. It was difficult to take any quantitative counts of incidence, as the insects are small and found in large numbers on the plant. Therefore the table gives only the number of plants positive for aphids, irrespective of the intensity of infestation. Although it was observed that in the untreated plots aphid infestation was much heavier, there was not much difference in the number of plants infested. The number of plants attacked by aphid in the endrin treated plot and the control is given in Fig. 2.

Sylepta derogata : The leaf roller started appearing when the crop was 12 weeks old and persisted in small numbers right through the season. Damage due to leaf roller was not heavy. The leaf roller incidence in the various treatments is given in Table 1. A comparison of some of the better insecticides with the control is given in Fig. 2.

Earias fabia : The spotted boll worm was observed once during boll formation and with one spraying with insecticide it almost completely disappeared. The number of bolls attacked was about 5 per cent which is very low compared to observations made by Deshpande and Nadkarny (1936) in Bombay State where damage by boll worm was as high as 50 per cent.

Oxycarenus latus : was seen on the opened bolls but no serious damage was observed.

Dysdercus similis and Pectinophora gossypiella : were very scarce during the period of observation.

Results and Discussions

Of the insecticides tried, endrin at a concentration of 1 fl. oz. in 2 gallons water gave very good control of the pests and significantly higher yields than the untreated control. Walker and Haidari (1954) also reported excellent increase in yields in Iraq by the use of endrin at the rate of 1 lb. per acre against aphids. The yield figures are given in Table 3. In three 30 ft. by 20 ft. plots, the yield from the endrin treated plots was 66.2 lb., the equivalent of 1,602 lb. per acre, and from the best of the three plots was 24 lb. which works out to 1,766 lb. per acre. The untreated control gave only 41.6 lb. in three plots—the equivalent of 1,006 lb. per acre. The yield from the entire

trial area of about an acre was 1,207.8 lb. These yields were obtained inspite of the average stand of the crop being less than 60 per cent of the expected stand. D.D T. at 1 fl. oz. in 2 gallons water and E.P.N. at 1 fl. oz. 3 gals. water gave good control of pests and significantly higher yield than the control. D.D.T. at 1 fl. oz. in 1 gallon water gave very low yields and this was not unexpected as the stand in the plots was very poor.

The cost per application with endrin at the above dose would work out to about Rs. 12 at the rate of about 40 gallons of spray liquid per acre. The total cost per season would be Rs. 60 to Rs. 75 per acre for six applications. The yield increase by this application would more than adequately compensate the cost of treatment with insecticide.

Summary

Insect pests can cause severe damage to cotton crops in the dry zone and limit production. Observations made at Maha Illuppallama reveal that the more important pests are : (1) *Aphis gossypii* G.—the cotton aphid, (2) *Sylepta derogata* F.—the cotton leaf roller, (3) *Earias fabia* Cramb.—the spotted boll worm, and (4) *Oxycarenus latus* Kirby—the dusky cotton bug. Although, *Dysdercus similis* Freeman—the red cotton bug, and *Pectinophora gossypiella* Saund—the pink boll worm, had been observed on the crops during two seasons, they do not seem to cause much damage in these areas.

Trials were conducted at Maha Illuppallama to find a suitable insecticide for control. B.H.C., D.D.T., Dipterex, Endrin, E.P.N. (Ethyl-p-nitrophenyl benzenethiophosphonate) and Gusathion were tried at two concentrations each applied (i) at fortnightly intervals and (ii) according to pest incidence. Endrin gave the best control of all the pests and gave significantly higher yields than the untreated checks. D.D.T., and E.P.N., also gave good control of pests.

ACKNOWLEDGMENTS

The authors wish to thank Mr. P. Manickavasagar, Plant Protection Officer, for his help in the early stages of the trial and Mr. J. Amarasena, Laboratory Assistant, for his assistance during the entire studies.

LITERATURE CITED

1. DESHPANDE, B. P. and NADKARNY, N. T., 1936. The spotted boll worm of cotton (*Earias fabia* Stoll) in South Gujerat, Bombay Presidency. *Sci. Monogr. Imp. Counc. Agric. Res. India, 10 : 208.*

2. HARBORD, G., 1937. Notes on village cotton cultivation in the Hambantota District during 1936-37. *Tropical Agriculturist 89 : 361.*

3. WALKER, R. L. and HAIDARI, H. S., 1954. Effectiveness of certain insecticides against the spiny boll worm in Iraq. *J. Econ. Ent., 47 : 367-69.*

TABLE 1

Percentage cotton plants attacked by Sylepta derogata **the cotton leaf roller**

Treatments		*Percentage cotton plant attacked*				
		Two weeks after each treatment				
		1	*2*	*3*	*4*	*5*
B.H.C.	Low 1	2	2	3	1	1
	Low 2	2	2	4	1	1
	High 1	3	3	2	2	1
	High 2	3	3	4	1	1
D.D.T.	Low 1	2	2	2	1	1
	Low 2	1	2	1	0	1
	High 1	3	3	2	1	1
	High 2	2	2	1	1	1
Dipterex	Low 1	2	3	1	1	1
	Low 2	2	5	3	6	1
	High 1	3	8	4	12	1
	High 2	4	2	4	7	1
Endrin	Low 1	0	1	1	0	1
	Low 2	2	1	1	1	1
	High 1	1	1	1	0	0
	High 2	2	1	1	0	0
E.P.N.	Low 1	2	5	1	1	1
	Low 2	1	1	1	1	1
	High 1	2	3	1	1	0
	High 2	4	2	2	1	1
Gusathion	Low 1	2	3	2	5	1
	Low 2	2	5	5	8	1
	High 1	5	5	4	8	1
	High 2	7	12	6	10	1
Control		5	14	10	14	16

TABLE 2

Percentage cotton plants attacked by *Aphis gossypii*—the cotton aphid—in sixty selected plants from each treatment

Treatment		*Percentage cotton plants attacked*						
		Before treatment	*Two weeks after each treatment*					
			1	*2*	*3*	*4*	*5*	*6*
B.H.C.	Low 1	47	51	52	59	22	65	65
	Low 2	27	59	63	57	25	56	80
	High 1	27	26	72	45	18	47	70
	High 2	33	23	77	48	33	53	81
D.D.T.	Low 1	47	53	63	53	33	67	75
	Low 2	20	70	62	53	15	56	66
	High 1	27	56	63	48	23	59	80
	High 2	30	63	67	68	42	68	85
Dipterex	Low 1	13	46	60	43	10	56	75
	Low 2	20	69	43	50	20	56	75
	High 1	27	46	66	50	18	51	65
	High 2	33	63	70	68	20	54	81
Endrin	Low 1	40	43	50	43	32	57	64
	Low 2	20	39	37	38	27	59	63
	High 1	13	38	57	37	15	31	79
	High 2	20	33	70	43	18	59	67
E.P.N.	Low 1	40	57	63	66	22	57	75
	Low 2	27	57	43	48	38	57	81
	High 1	27	46	66	72	32	53	82
	High 2	40	49	82	68	17	70	86
Gusathion	Low 1	27	57	53	66	10	77	67
	Low 2	33	56	66	55	35	75	68
	High 1	33	66	67	60	23	77	79
	High 2	47	49	70	55	43	56	79
Control		20	59	75	86	55	75	82

TABLE 3

Cotton yields in pounds, obtained from 30 ft. × 20 ft. plots in three replicates during Maha 1959-60

Treatment		*Weight of cotton in pounds*				*Yield in pounds per acre*
		Rep. 1	*Rep. 2*	*Rep. 3*	*Total*	
B.H.C.	Low 1	14·7	13·3	13·5	41·5	1,004
	Low 2	13·3	12·4	14·3	40·0	968
	High 1	15·5	17·3	12·4	45·2	1,093
	High 2	12·2	17·6	18·2	48·0	1,162
D.D.T.	Low 1	24·2	21·4	16·8	62.4	1,511
	Low 2	16·7	17·3	17·5	51·5	1,246
	High 1	15·4	10·4	15·6	41·4	1,002
	High 2	15·1	19·7	12·1	46·9	1,135
Dipterex	Low 1	20·0	16·3	16·7	53·0	1,282
	Low 2	17·1	12·4	15·4	44·9	1,086
	High 1	16·8	13·8	14·4	45·0	1,089
	High 2	15·0	14·1	14·0	43·1	1,043
Endrin	Low 1	14·4	14·4	18·9	47·7	1,154
	Low 2	19·9	16·3	16·0	52·2	1,263
	High 1	22·0	20·2	24·0	66·2	1,602
	High 2	22·5	16·2	14·0	62·7	1,275
E.P.N.	Low 1	13·7	17·0	14·8	45·5	1,101
	Low 2	14·7	11·7	12·4	38·8	941
	High 1	15·8	19·4	21·8	57·0	1,379
	High 2	19·2	21·0	20·9	61·1	1,478
Gusathion	Low 1	13·3	14·6	17·9	45·8	1,108
	Low 2	16·6	13·0	11·7	41·3	999
	High 1	17·9	13·6	15·9	47·4	1,147
	High 2	16·1	15·3	16·2	47·6	1,159
Control		18·6	8·6	14·4	41·6	1,006
	Total	420·7	387·3	399·8	1,207·8	—

Fig. 1.—Percentage plants attacked by cotton leaf roller in plots treated with endrin, D. D. T. and E. P. N. and in the untreated control.

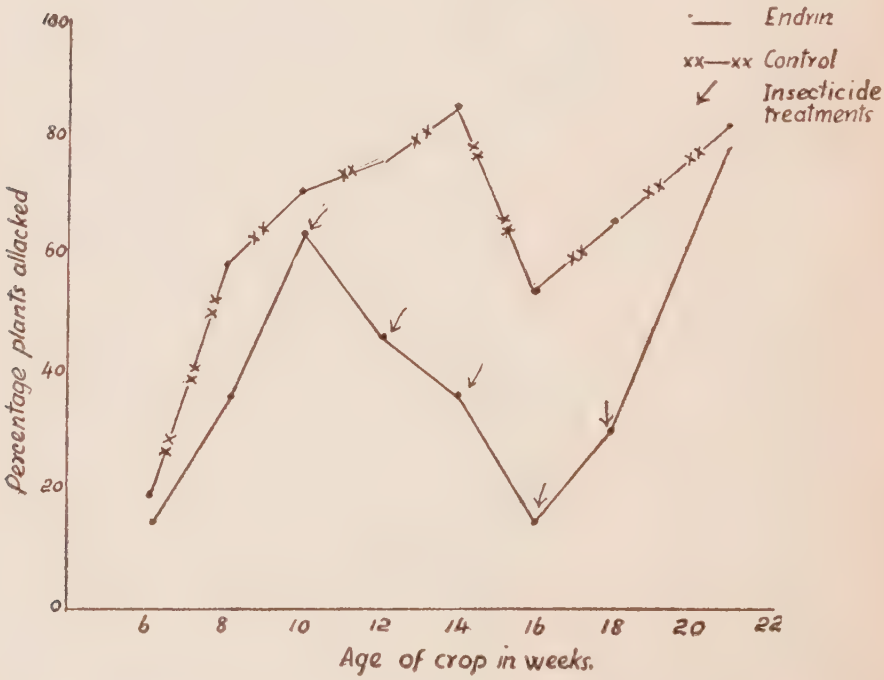


Fig. 2.—Percentage plants attacked by cotton aphid in the plots treated with endrin and in the untreated control.

METEOROLOGICAL REPORT

Summary for October-December, 1960

UNSETTLED weather towards the end of the month, associated with a low pressure area to north of Ceylon, was the dominant feature of the weather during October. Rain and thundershowers were heavy and widespread, several stations recording daily falls over 5 inches. Low lying areas of Colombo and its suburbs were threatened by floods and gusts of strong wing, reaching gale force at times, were experienced along the west coast. With the passage of this low pressure in a northerly direction the heavier falls were confined to the south-western parts of the Island. During the early part of the month the weather was dry, practically over the whole Island, on account of the passage over Ceylon of some dry westerly winds. The nights were unusually cold during this period, the minimum temperature being several degrees below normal. The afternoon and evening thundershowers which became evident from about the 12th gradually increased in extent and were widespread from about the 19th. The greater monthly totals of rainfall (totals over 20 inches) occurred among the central hills, while the lowest totals (below 5 inches) were found chiefly in the northern and eastern parts of the Island. Rainfall, on the whole, was below normal, excesses occurring chiefly among and to the east of central hills and along the west central coast. The bigger deficits (of the order of 10 inches) occurred on the south-western slopes of the central hills. The highest excesses (between 5 and 10 inches) were recorded in the Nuwara Eliya District. There were 18 daily falls of over 5 inches, the highest being 6.46 inches at Eladuwa Estate, Paiyagala, on the 28th.

Several successive low pressure systems in the Bay of Bengal and a solitary low pressure area in the Arabian Sea, in addition to the normal intermonsoon thunder acitvity, were responsible for the continuous wet weather that was experienced in certain parts of Ceylon during November almost till the end of the month. The areas affected were the Jaffna Peninsula, the western and north-western coastal belt and the neighbourhood of Kandy. These regions experienced rainfall on 20 to 25 days of the month, about 5 days in excess of the average. The rainfall was considerably heavy in Jaffna and Mannar Districts from the 14th to 16th, when several daily amounts over

5 inches were recorded. These rains resulted in floods in Jaffna Peninsula, causing great inconvenience to many people, while a number of tanks were damaged in the Northern and North-Central Provinces. The heaviest rainfall, with totals over 20 inches, were recorded chiefly in the Jaffna and Puttalam Districts and in the central parts of the Island, while the least rainfall, where the totals were below 5 inches was found in the Hambantota District. Rainfall was generally below normal in the south-western lowlands and mid-country, east of the central hills and along the eastern coastal areas, and above normal elsewhere, the biggest deficits being of the order of 10 inches and the highest excesses of the order of 15 inches. There were about 12 daily falls of over 5 inches, the highest being 8.30 inches at Talaimannar on the 16th.

Intermonsoon thundershowers of November continued for a few days in December too. North-East monsoon conditions became evident from about the 7th, when monsoon showers were experienced in the northern and eastern parts, with scattered evening thundershowers in the South-West. During the second half of the month the weather over the Island was practically dry, except for fairly widespread light to moderate rain from the 27th to 29th, caused by a shallow depression in South-west Bay of Bengal. Rainfall for December was consequently below normal throughout the Island, the higher deficits (between 10 and 15 inches) occurring on the North-eastern slopes of the central hills and in the Eastern Province. The greater monthly totals of rainfall (over 10 inches) were experienced along the north-eastern slopes and to the east of the central hills while least rainfall (totals below 2 inches) occurred chiefly along the south-western slopes of the central hills and in the low country between Colombo and Puttalam. There were only two daily falls of over 5 inches, the higher one being 5.41 inches on the 2nd at Mahawalatenne.

D. J. JAYASNGHE,
Director.

Department of Meteorology,
Bullers Road, Colombo 7, February 17, 1961.

METEOROLOGICAL REPORT

OCTOBER, 1960

Station	Temperature				Humidity		Amount of Cloud	Rainfall			
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min.)		Amount	Offset	Rain Days	Offset
	°		°		%	%		Inches	Inches		
Anuradhapura	92·7	+3·8	73·3	—0·2	64	90	4·8	8.30	—1·42	10	— 6
Badulla	86·3	+3·5	65·2	—0·3	68	95	5·1	15·19	+6·30	20	+ 1
Batticaloa	87·1	+0·1	75·6	+0·3	74	88	4·0	3·32	—3·87	5	— 8
Colombo	85·3	+0·5	73·3	—1·5	82	93	6·0	13·89	+0·18	13	— 9
Diyatalawa	78·7	+2·4	60·8	+0·3	67	75	5·3	8·32	—0·86	18	— 2
Galle	83·1	+0·2	75·3	—0·1	79	88	5·0	5·32	—6·73	14	— 6
Hambantota	86·5	+0·3	75·5	+0·2	74	86	4·6	3·37	—1·39	9	— 4
Jaffna	86·1	+0·4	78·0	+0·4	80	89	5·3	8·60	—0·60	12	— 0
Kandy	84·3	—0·9	67·5	—0·4	68	90	5·3	6·25	—5·36	16	— 2
Kankesanturai	88·5	+1·6	79·4	+2·3	74	80	5·0	6·09	—3·53	11	0
Kurunegala	89·8	+2·7	72·8	—0·4	69	93	5·6	12·32	—2·54	16	— 4
M'Illuppallama	91·6	+3·5	72·2	—1·1	62	88	4·9	6·91	—2·55	10	— 5
Mannar	87·3	+0·5	77·1	—0·3	82	91	6·0	5·97	—0·61	11	0
Nuwara Eliya	69·7	+2·1	52·7	+0·5	73	84	5·2	10·30	+0·54	20	— 2
Puttalam	88·0	+1·7	74·8	—0·8	68	86	5·4	4·61	—2·82	12	— 2
Ratmalana	86·1	+1·0	74·8	—0·1	74	90	6·0	13·86	+0·66	12	—
Ratnapura	90·1	+3·0	71·8	—1·0	66	88	5·4	11·85	—6·16	13	—10
Talawakele	72·8	—0·3	56·8	—1·0	79	91	5·2	8·88	—1·18	19	—
Trincomalee	90·0	+2·0	76·5	+0·9	65	79	5·0	3·19	—6·36	10	— 6
Mullaitivu	91·3	—	75·0	—	68	88	4·3	4·85	—6·71	11	—
Katunayake	86·1	—	74·0	—	76	93	5·6	16·51	—	13	—
Vavuniya	92·5	—	72·9	—	60	85	5·2	4·31	—4·49	14	—

NOVEMBER, 1960

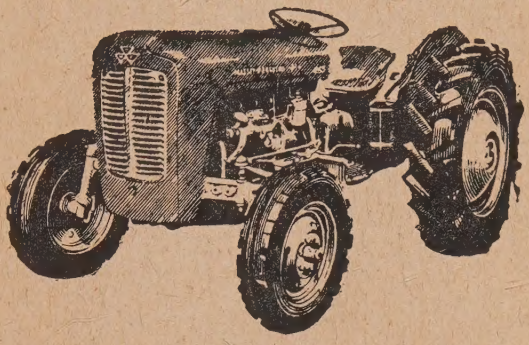
Station	Temperature				Humidity		Amount of Cloud	Rainfall			
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min.)		Amount	Offset	Rain Days	Offset
	°		°		%	%		Inches	Inches		
Anuradhapura	84·7	—1·1	72·3	+0·9	82	93	6·0	13·20	+2·53	22	+ 3
Badulla	80·1	+0·8	65·8	+0·4	81	97	6·4	10·16	—0·09	24	+ 2
Batticaloa	85·3	+1·1	74·7	+0·5	79	90	5·8	13·55	—0·31	19	+ 1
Colombo	84·1	—1·1	72·7	—0·6	84	95	6·4	16·75	+3·66	21	+ 1
Diyatalawa	74·7	+0·4	60·4	+0·6	82	94	6·5	13·61	+3·19	24	+ 2
Galle	83·3	—0·3	74·5	+0·3	79	88	6·0	8·53	—3·48	19	0
Hambantota	85·9	+0·5	74·5	+0·5	75	88	5·9	7·84	+0·27	13	— 3
Jaffna	81·8	—2·3	75·1	+0·3	87	95	7·2	21·55	+4·28	23	+ 5
Kandy	80·9	—2·0	67·6	+0·2	77	90	7·0	13·63	+2·93	26	+ 8
Kankesanturai	81·6	—2·6	75·0	—0·4	88	93	7·3	26·11	+8·97	24	+ 9
Kurunegala	84·6	—2·3	72·0	+0·2	81	98	7·0	15·83	+3·44	23	+ 4
M'Illuppallama	84·5	—1·1	71·5	+1·0	80	90	6·4	16·12	+6·16	22	+ 6
Mannar	83·7	—0·9	76·0	+0·3	84	88	7·3	14·62	+4·43	24	+ 7
Nuwara Eliya	66·8	—1·0	53·7	+2·6	80	82	7·0	11·75	+2·56	23	+ 1
Puttalam	83·7	—2·0	73·5	+0·4	77	88	6·8	21·71	+11·58	22	+ 4
Ratmalana	85·1	—1·3	73·8	+0·9	76	90	6·6	12·88	+0·76	19	—
Ratnapura	87·4	—0·4	71·5	—0·7	71	88	6·2	7·57	—7·22	19	— 3
Talawakele	71·3	—2·1	57·5	+0·5	87	94	7·0	11·05	+2·55	25	—
Trincomalee	84·0	+0·4	74·8	0	80	88	7·0	9·60	—4·34	26	+ 7
Mullaitivu	83·2	—	74·3	—	84	93	6·8	18·39	+2·34	26	—
Katunayake	84·6	—	73·0	—	80	95	6·4	17·86	—	18	—
Vavuniya	84·5	—	72·3	—	78	90	7·4	16·32	+3·27	23	—

Station	DECEMBER, 1960									
	Temperature				Humidity		Amount of Cloud	Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	% Day	% Night (from Min.)		Amount	Offset	Rain Days	Offset
	°		°					Inches	Inches		
Anuradhapura	84·0	+0·7	70·6	+0·6	78	85	5·0	3·09	—4·51	16	0
Badulla	78·0	—1·4	65·4	+0·9	81	95	5·8	3·24	—7·99	14	—7
Batticaloa	83·2	—1·3	75·3	+1·7	78	88	5·2	6·78	—10·21	13	—7
Colombo	86·7	—1·2	72·7	+0·4	75	88	5·0	2·10	—3·51	10	—2
Diyatalawa	73·0	—1·0	59·2	+0·6	81	94	6·5	1·79	—6·28	15	—5
Galle	84·4	—0·9	73·8	+0·5	78	88	5·0	1·14	—6·68	8	—6
Hambantota	85·5	—0·8	74·1	+1·0	73	86	4·0	2·50	—3·11	8	—5
Jaffna	83·6	—1·1	73·8	+0·8	76	90	5·2	1·68	—8·71	11	—3
Kandy	81·9	—0·1	66·9	+1·1	70	87	5·8	2·30	—6·57	11	—2
Kankesanturai	83·2	—0·5	75·9	+1·0	78	82	5·1	2·66	—7·08	11	—1
Kurunegala	86·0	—0·3	71·0	+0·3	71	95	5·0	1·34	—5·44	7	—6
M'Illuppallama	85·3	—1·9	69·9	+0·3	74	90	5·4	6·03	—2·03	12	—1
Mannar	83·7	—0·9	76·2	+1·3	78	84	5·3	2·99	—4·80	12	—2
Nuwara Eliya	67·7	0	51·4	+2·4	78	88	5·5	1·55	—6·26	12	—5
Puttalam	86·1	—1·3	71·5	+0·3	68	88	5·2	1·13	—4·42	8	—5
Ratmalana	87·9	—1·5	72·8	+1·1	66	90	5·2	0·74	—5·91	8	—
Ratnapura	90·3	—2·2	71·2	—0·4	65	88	6·1	2·89	—6·23	12	—4
Talawakele	74·1	—0·6	56·7	—0·6	71	85	4·8	0·59	—4·59	8	—
Trincomalee	82·7	—1·6	77·2	—2·3	76	78	5·8	4·51	—8·49	10	—8
Mullaitivu	83·1	—	76·3	—	77	82	4·9	5·06	—8·46	14	—
Katunayake	88·0	—	72·4	—	68	90	4·2	1·04	—	8	—
Vavuniya	84·7	—	70·2	—	75	93	5·2	5·61	—5·97	13	—

Get the best out of YOUR LAND with....

MASSEY-FERGUSON 35

The world's greatest light tractor, with a great new three-cylinder diesel engine.



Landmaster 150

To produce more, quicker, you need the Landmaster 150

KESTREL

The name to remember for Sulphur Dusting, Fertilising and Spraying equipment.

AMES IRRIGATION EQUIPMENT

There's an Ames Irrigation system, SPRINKLE, FORROW, FLOOD, for all conditions everywhere.

You get the best from Browns

BROWNS GROUP B G ESTABLISHED 1823

BROWN & CO. LTD.

AGRICULTURAL DIVISION, RATMALANA

PRINTED AT THE GOVERNMENT PRESS, CEYLON.